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Tech Notes

JANUARY 1988

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Tech Notes

Highlighting Selected U.S. Government Technology & Resources

JANUARY 1988

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Published monthly by the National Technical Information Service (NTIS), Tech Notes bring togeather individual one to two page fact sheets prepared by Federal agencies, their laboratories, or contractors. These fact sheets highlight current Federal technology determined to have commercial or practical application. Topics cover new processes, materials, techniques, software, instrumentation, and resources.

Some of the current sources are the Department of the Navy, Department of the Army, NASA, Department of Energy , Environmental Protection Agency, Department of the Interior, and the Department of Agriculture.

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Sources of Further Backup Information

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However, there are cases where NTIS is the source for backup documentation. In these cases, use the order form at the end.

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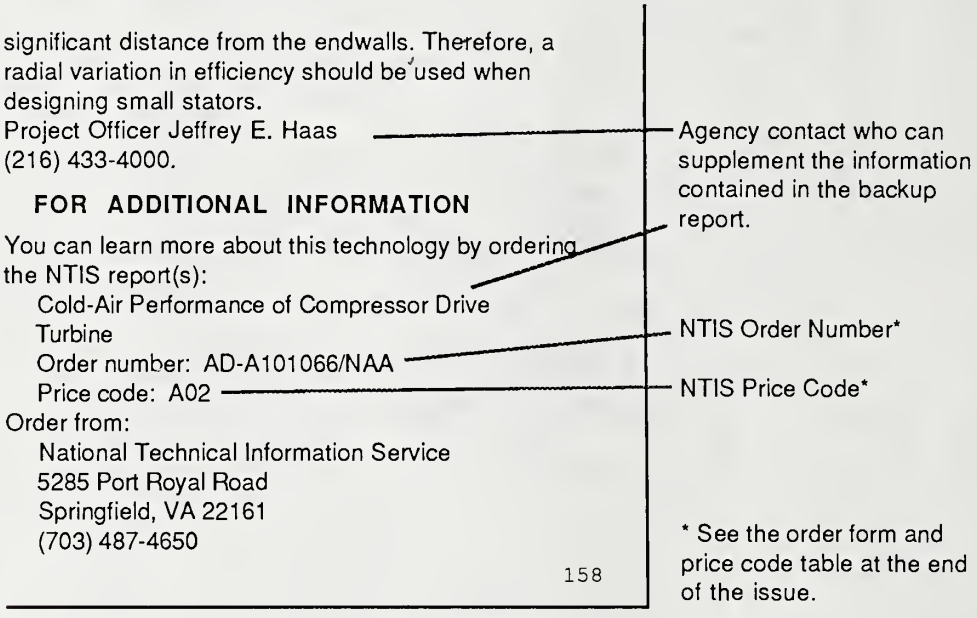
significant distance from the endwalls. Therefore, a radial variation in efficiency should be used when designing small stators.
Project Officer Jeffrey E. Haas
(216) 433-4000.
FOR ADDITIONAL INFORMATION
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Cold-Air Performance of Compressor Drive Turbine
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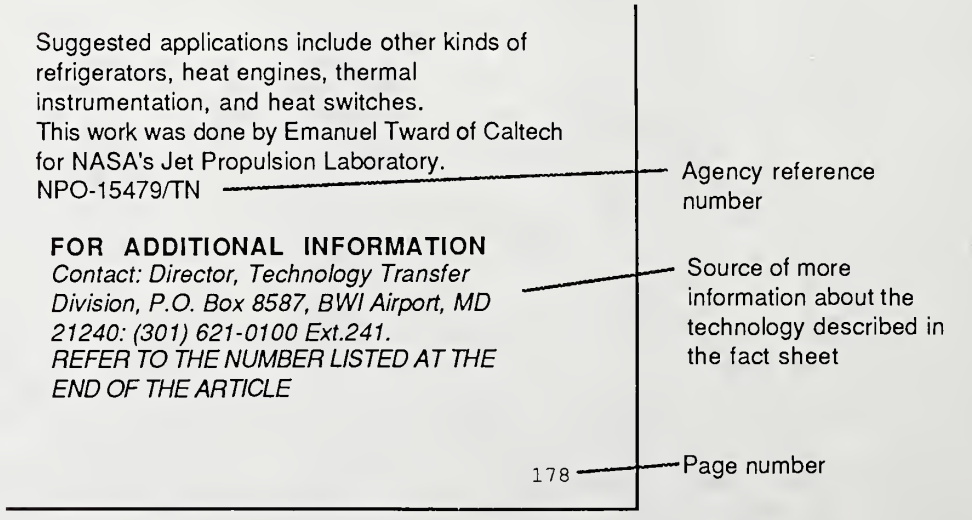
Suggested applications include other kinds of refrigerators, heat engines, thermal instrumentation, and heat switches.
This work was done by Emanuel Tward of Caltech for NASA's Jet Propulsion Laboratory.
NPO-15479/TN
FOR ADDITIONAL INFORMATION
Contact: Director, Technology Transfer Division, P.O. Box 8587, BWI Airport, MD 21240: (301) 621-0100 Ext.241.
REFER TO THE NUMBER LISTED AT THE END OF THE ARTICLE
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13 Electronically Tuned Microwave Oscillator — Features include low phase noise and frequency stability.
14 Highly Stable Microwave Resonator — Superconducting walls on a sapphire-filled cavity make a low-loss device.
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16 Electronically Controlled Resistor Bank — Resistance is quickly varied in small steps over a wide range.
17 Computerized Torque Control for Large dc Motors — The speed and torque ranges in the generator mode are extended.
18 FM-to-Digital Converter — A circuit includes an array of low-cost multivibrators. (Licensing Opportunity)

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Testing & Instrumentation

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Agriculture & Food

1 Fish Oil Refining System

2 Artificial Gene Aids Study of Oilseed Crops

3 Easy Way to Automate Irrigation Valves (Licensing Opportunity)

NOAA Technology Brief

National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northwest and Alaska Fisheries Center

Fish Oil Refining System

NOAA has developed an inexpensive system for refining highly purified Omega-3 fatty acids in fish oils, previously manufactured at extremely high cost. The manufacture of Omega-3 compounds previously cost up to $2,000 per gram; the NOAA method ultimately may bring the cost down to $5 a gram or less.

Heart of the system is a 6-foot stainless steel column in which supercritical carbon dioxide is introduced to fish oils containing the desired fatty acids. By varying the temperatures -- up to 212 degrees Fahrenheit -- and the pressure -- up to 2500 PSI -- inside the column, scientists can dissolve and isolate the components of fish oils, including eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA).

The current batch unit system presently can produce 70 grams per day of over 90 percent-pure EPA, and 40 grams of DHA. Research continues on a larger continuous unit, designed to produce up to 4.5 kilograms (10 pounds) per day.

Additional information on the fish oil refining system is available from NOAA ORTA, Suitland Professional Center (SPC), Room 307, Suitland, Maryland 20233. Telephone (301) 763-4240.

United States
Department of
Agriculture

Research Technology
Agricultural Research Service

Artificial Gene Aids Study of Oilseed Crops

Segments of DNA have been joined together by Agricultural Research Service scientists to make a synthetic plant gene. The new gene carries the "blueprint" for a key protein needed for soybeans and other oilseed plants to produce oil.

Going a step further, the scientists have successfully inserted the new gene into a common bacterium *(Escherichia coli)*. Once in the bacterium's genetic makeup, the gene directs production of acyl carrier protein. In plants, this protein is needed for several steps in the synthesis of fatty acids that are components of cell membranes and of oils stored in plant seeds.

"Now enough of the protein can be made and purified to thoroughly study plant fatty acid synthesis," says biochemist John B. Ohlrogge, who headed a research team investigating fatty acids when he was employed at the ARS Northern Regional Research Center in Peoria, IL. Ohlrogge is continuing studies on the protein at Michigan State University in research funded through a USDA competitive grant.

Forming the synthetic gene for acyl carrier protein was made easier by a new laboratory instrument called a DNA synthesizer to produce nucleotides—DNA fragments—from simpler organic chemicals. Team member Phillip D. Beremand, a biochemist, constructed the gene by using enzymes to link together 16 of these fragments.

In theory, any gene that might be found in nature can be constructed in the laboratory. In natural genes, as in synthetic ones, building blocks—nucleic acids—are joined in a sequence that serves as a language. Through a series of steps, this nucleic acid language is translated to specify the amino acid sequence of proteins that a plant produces.

"In medical research, making genes chemically outside of living cells is becoming routine," Beremand says, "We applied the technology in a long-range quest toward increasing the commercial value of oilseed crops."

It's too early to tell whether this research may help scientists develop genetically engineered oilseed crops that produce higher yields or more healthful vegetable oils.

John B. Ohlrogge is at the Department of Botany and Plant Pathology, Michigan State University, East Lansing, MI 48824-1312. Phillip D. Beremand is at the USDA-ARS Northern Regional Research Center, 1815 North University St., Peoria, IL 61604.

United States Department of Agriculture

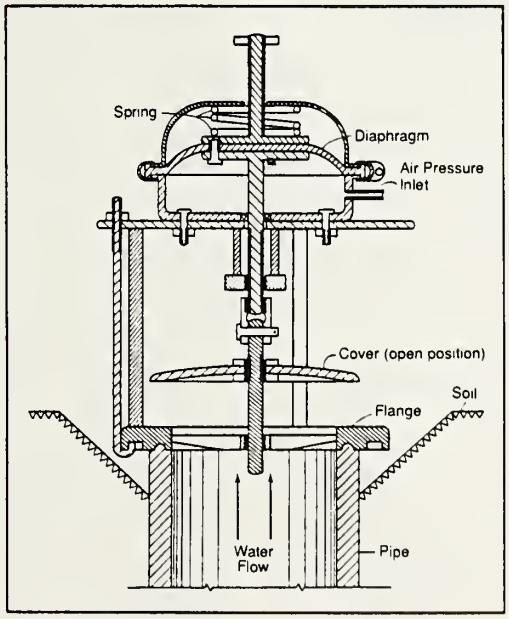
Licensing Opportunity

Research Technology
Agricultural Research Service

Easy Way to Automate Irrigation Valves

This ingenious device readily converts several kinds of manual irrigation valves for automatic operation using compressed air controls.

Automating irrigation this way makes it easier for farmers to improve efficiency. And because it requires air pressure to keep valves open, any electrical or equipment failure automatically shuts the valves, preventing accidental releases of water common to nonpneumatic systems.



Retrofitted alfalfa valve

The new device clamps on to the top of an irrigation valve without any changes other than replacing the handle and threaded stem which are used to open and close the valve.

When pressurized air enters the chamber at the top of the upper shaft, a diaphragm compresses a spring, raising the shaft and turning the water on. When the air is vented from the chamber, the spring pushes the shafts down and stops the flow of water.

For technical information, contact Clayton H. Gibson or Ronald E. Yoder, USDA-ARS Irrigation and Drainage Research, 764 Horizon Dr., Suite 215, Grand Junction, CO 81506. *Patent Application Serial No. 06/892,006, "Retrofit Device for Alfalfa Valves."*

For Additional Information:

Inquiries concerning rights for commercial use of this invention should be addressed to

Office of Federal Patent Licensing
Center for the Utilization of Federal Technology
Room 13R, NTIS
Springfield, VA 22161
(703) 487-4738

Refer to Patent Application 6-892,006/TN

Computers

4 Data Bus Adapts to Changing Traffic Level — Access becomes timed when collisions threaten.

5 Navy Microcomputers Enable Quick-Response Surveys

Software

6 Computer-Aided Management of Emergency Operations (CAMEO)

7 A Computer System for Mission Managers — The system helps the mission manager coordinate diverse functions and produce documentation.

8 FORTRAN Algorithm for Image Processing — Applications might include scientific, industrial, and biomedical imaging.

Other items of Interest

38 Feedforward and Feedback Schemes Linearize Responses to Control Inputs

NASA Tech Brief
National Aeronautics and Space Administration
Goddard Space Flight Center, Greenbelt, Maryland

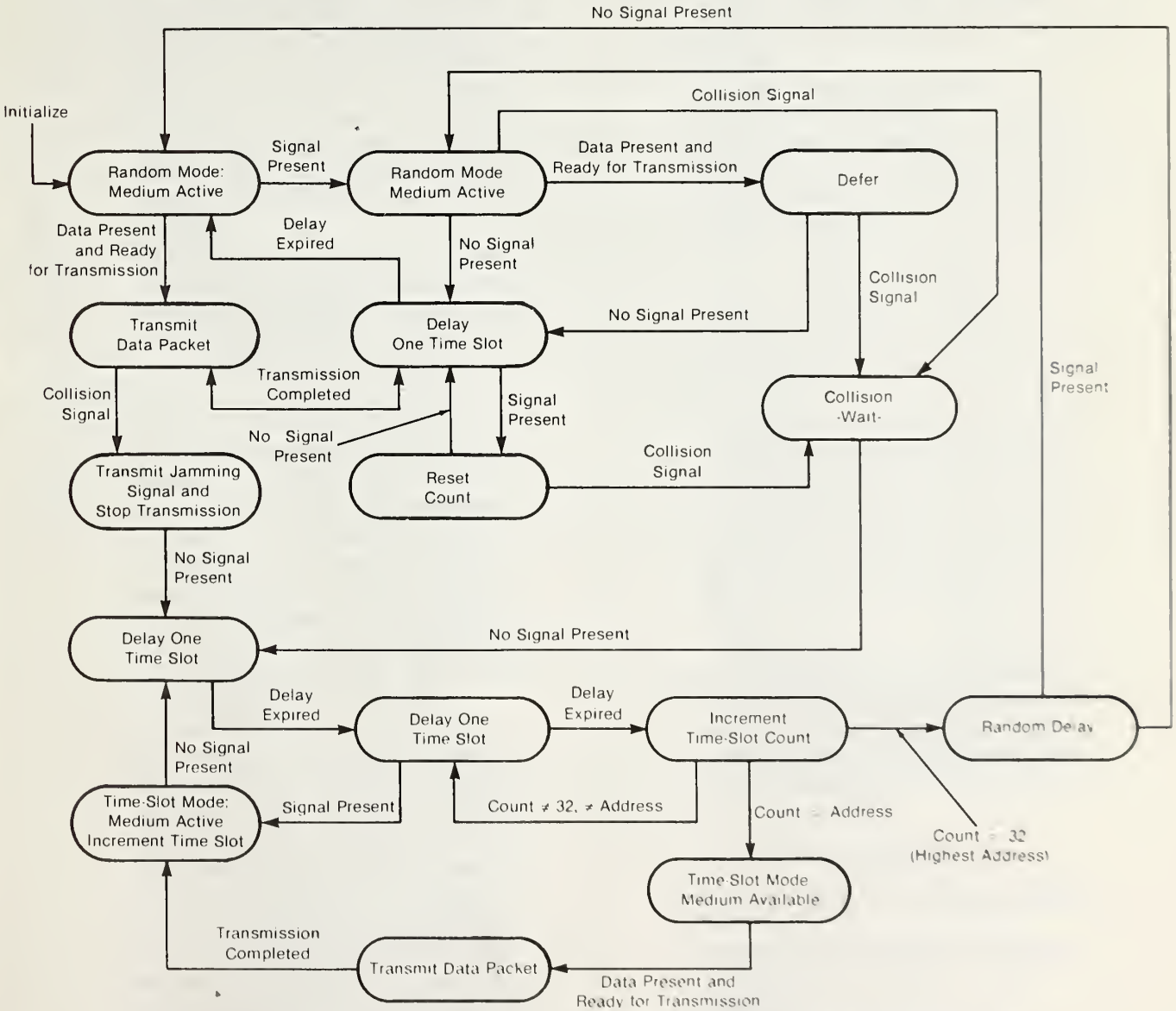
Data Bus Adapts to Changing Traffic Level

Access becomes timed when collisions threaten.

A two-mode scheme is used to grant terminals access to a data bus. The scheme causes the bus to alternate between random accessibility and controlled accessibility to optimize performance and adapt to changing data-traffic conditions. The bus is part of a 100-Mb/s optical-fiber-packet data system.

When traffic on the bus is light, the random-access mode allows the most efficient use of the bus. When traffic increases, the bus changes to the controlled-access mode, which gives all terminals an equal opportunity to send data, even in the heaviest traffic.

The figure is a state diagram of the scheme. In the random-access mode, any terminal can use the bus whenever it



This **State Diagram** illustrates the controlled- and random-access protocols and the transitions between them.

needs to send out a packet of data. If the bus is busy when a terminal requests it, the terminal automatically refrains from transmitting until the bus is free. Of course, two terminals may sometimes gain access to the bus at the same time; in that case, their data packets are said to "collide" and are recorded as not having been sent.

When such a "collision" occurs, all of the terminals in the network cease attempting to transmit data, and the entire network changes to the controlled-access mode. In a preset sequence, each terminal is then allocated its own 1.6-μs timeslot, during which it can gain access to the bus. When a terminal needs to send a message, it must wait until its timeslot comes up to do so. After the terminal has ended its transmission, the sequence of timeslots is resumed. The terminal that recently transmitted may not use the bus again until all the other terminals have been offered their timeslots.

This strict control prevents a few terminals from monopolizing the bus. When all timeslots have been proffered and all pending bus requests have been satisfied, the network reverts to the random-access mode.

This work was done by Eugene Lew, John DeRuiter and Mike Varga of Sperry Aerospace and Marine for **Goddard Space Flight Center**. *GSC-12967 /TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD. 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THE ARTICLE

NAVY
Domestic Technology Transfer Fact Sheet

Navy Microcomputers Enable Quick-Response Surveys

Popular management books emphasize employee involvement in decisionmaking at all levels in organizations. This has led to a resurgence in the use of surveys, as managers need to better understand the attitudes, beliefs and opinions of employees prior to making decisions that affect their working lives.

A number of potential drawbacks exist, however, when traditional paper-and-pencil surveys are used. These surveys typically require extensive time, effort, and funds to construct, duplicate, collate, administer, code, analyze and summarize. These obstacles often prevent timely results from being obtained and utilized.

Researchers at the Navy Personnel Research and Development Center (NPRDC) in San Diego, California, have developed two experimental microcomputer-based survey systems that alleviate many of these drawbacks. The systems, known as CENSUS (Computerized Executive Networking Survey System) and MASQ (Microcomputer-based Assessment, Surveys and Questionnaires), were originally developed to help Navy civilian policymakers conduct quick-reaction surveys of Navy employees. In one systems test of CENSUS, a survey was administered to several hundred individuals, analyzed, and a briefing prepared within 24 hours.

The CENSUS system is most appropriate for large-scale surveys, where the respondents are located in one site. CENSUS utilizes an IBM PC/AT host microcomputer, in conjunction with the multiuser XENIX operating system, to collect responses from up to sixteen users, working simultaneously on computer terminals. The computer automatically stores the answers and quickly analyzes them, using statistical packages, eliminating the tedium and costs associated with paper-and-pencil surveys. Survey administration is further streamlined through CENSUS's branching capabilities, whereby a survey can be custom-tailored to individuals. Thus, a survey that includes questions about marriage would skip those items for unmarried persons. In previous tests with the CENSUS system, users made fewer errors (e.g., omissions, incorrect branching) than those completing a comparable paper and pencil survey. Additionally, respondents found the electronic survey to be more enjoyable.

Because many organizations do not possess XENIX-based equipment, but do use stand-alone microcomputers for word processing or database management, an MS-DOS-based prototype of the CENSUS system, MASQ, was developed recently. MASQ is particularly useful when surveys need to be simultaneously conducted at different locations. The MASQ program allows a microcomputer-based survey to be developed, run, stored, and analyzed on any IBM or IBM-compatible microcomputer, including portables. Although MASQ does not have the multiuser features of CENSUS, its presentation of survey items is identical to CENSUS. MASQ allows a quick-reaction survey to be conducted without purchasing additional hardware or software.

Although still in a developmental stage, CENSUS provides a mechanism to improve attitude assessment by exploiting advances in technology. It has already proved capable of providing an economical and reliable way to rapidly conduct and analyze surveys.

For Additional Information:

Backup material on this effort is available from:

Navy Domestic Technology Fact Sheet
Reader Reply Service
Code E211
Naval Surface Weapons Center
Dahlgren, VA 22448-5000
(703) 663-8921

Refer to 120603/TN

NOAA Technology Brief

National Oceanic and Atmospheric Administration

National Ocean Service
Office of Oceanography and Marine Assessment

Computer Software

Computer-Aided Management of Emergency Operations (CAMEO)

Working with the Seattle Fire Department, NOAA developed a prototype system for toxic chemical emergencies known as Computer-Aided Management of Emergency Operations (CAMEO). Microcomputers containing CAMEO can be carried to the scene of chemical accidents and used by trained firefighters, police, paramedics, or other first responders.

CAMEO contains detailed city maps and chemical facility floor plans with a database that has compiled advice in the areas most critical to firefighters and first responders: personal protective measures, fire and explosion hazards, human health threats, evacuation recommendations, and spill cleanup procedures. Code Breaker, CAMEO's chemical identification database, is a simple and rapid way to converge on the identity of a specific chemical by allowing searches based on name fragments, labels, synonyms, and so on. CAMEO's atmospheric dispersion model can help judge the extent and duration of a chemical plume resulting from an accident, even to allowing the "footprint" of the chemical plume to be drawn by the computer on the same CAMEO map first used to locate the incident.

The system can also be used for contingency planning. The database can be amended to define high-risk areas through identifying possible accident locations near sensitive areas. Using such information, contingency planning efforts can focus on realistic accident simulations.

The CAMEO system was developed by John H. Robinson of the Hazardous Materials Response Branch. It uses an Apple MacIntosh computer with a combination of software designed for normal business use and specialized programs and information systems developed by NOAA. It is available to response authorities throughout the world.

Additional information about CAMEO can be obtained from NOAA ORTA, SPC, Room 307, Suitland, Maryland 20233. Telephone: (301) 763-4240.

NASA Tech Brief
National Aeronautics and Space Administration

Computer Software

A Computer System for Mission Managers

The system helps the mission manager coordinate diverse functions and produce documentation.

The Mission Managers' Workstation (MMW) is a personal-computer-based system providing data management and reporting functions to assist Space Shuttle mission managers. The full work station is composed of IBM PC hardware, packaged software, and custom software integrated into a friendly, menu-driven system. Before each Shuttle mission, a series of reports and flight-readiness documents must be issued and approved by the mission manager. MMW automates the production of these commit-to-flight documents. MMW also acts as a general productivity aid by providing central data storage and word processing.

There are four data bases incorporated in the package:

1. The Flights data base contains the bulk of information of planned Shuttle flights. It holds data applicable to launch, ascent, orbit, descent, cargo, structure weights, mission requirements and objectives, etc.
2. The Flight Experience data base stores combined information from previous flights.
3. The Mass Properties data base holds engineering specifications to aid in center-of-gravity modeling and calculations.
4. The Item Scheduler data base contains information about the series of events preceding launch day.

The work station allows the mission manager to relate events and stored data in a more timely and organized fashion. Using MMW, standard reports can be formatted, generated, edited, and electronically communicated with a minimum of clerical help.

MMW is written in PASCAL, BASIC, and assembler for interactive execution and has been implemented on an IBM XT computer operating under DOS with a central-memory requirement of approximately 640 K of 8-bit bytes and 10 Mbytes of hard-disk space. For full implementation, MMW also requires the following commercially available software: WordStar, SmartCom, Sidekick, R:Base 4000, Extended Batch Language, Fixed Disk Organizer, and File Path Program. This program was developed in 1985.

This program was written by Robert Tolchin, Sathy Achar, Tina Yang, and Tom Lee of Abacus Programming Corp. for **Johnson Space Center**. *MSC-21092 /TN*

FOR ADDITIONAL INFORMATION *CONTACT:*

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University of Georgia
Athens, GA 30602
(404) 542-3265

NASA Tech Brief
National Aeronautics and Space Administration

FORTRAN Algorithm for Image Processing

Applications might include scientific, industrial, and biomedical imaging.

A FORTRAN computer algorithm that contains various image-processing analysis and enhancement functions has been developed by the Lewis Research Center. The algorithm was developed specifically to process images of developmental heat-engine materials obtained with sophisticated nondestructive evaluation instruments.

Digital image processing has found many applications in scientific, biomedical, and industrial areas. Specific applications include the automatic classification of terrain through pattern-recognition techniques, the formation and enhancement of biomedical imagery, and the enhancement of radiographs and acoustic images of critical components containing possible flaws.

A variety of image-processing systems are available, and the level of software developed for each system varies. In some cases, the image processor is provided by the manufacturer as part of a minicomputer system. Such a system may include "user-friendly" software that requires little if any additional programming effort by the purchaser. In other cases, the image processor is purchased separately from a computer system and must be integrated into the system. Software may be provided and would have to be organized by an experienced computer programmer to develop powerful image-processing capability.

The subject FORTRAN program was developed for a Comtal/Grinnell 274 image processor interfaced with a Digital PDP 11/45 minicomputer. Its task file requires 64 kilobytes (125 blocks) of memory. The program was written using software routines provided by Comtal/Grinnell. Considerable additional FORTRAN programming was required to organize the routines to perform the desired functions. The program is organized into nine subroutines displayed on a main menu. The subroutines are chosen by the use of a computer keyboard. Within the subroutines are other routines, also selected via keyboard.

Some of the functions performed with this program include digitization, storage, and retrieval of images; image enhancement by contrast expansion, addition and subtraction, magnification, inversion, and bit shifting; display and movement of a cursor; display of a plot of the number of image pixels versus the gray level (gray-level histogram of the image); and display of a plot of the variation of the gray level as a function of position within the image. Possible applications of this program include scientific, industrial, and biomedical imaging for studies of flaws in materials, analyses of steel and ores, and pathology, respectively.

This program was written by Don J. Roth and David R. Hull of **Lewis Research Center.** *LEW-14291 /TN*

FOR ADDITIONAL INFORMATION
CONTACT:

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University of Georgia
Athens, GA 30602
(404) 542-3265

Electrotechnology

9 Full-Wave Analysis of Isolated and Coupled Microwave Transmission Lines Using the Finite Element Method

10 Transmitting Antenna Arrays Adaptable

11 Segmented Waveguide Program for Long Wavelength Propagation Calculations

12 Attaching Copper Wires to Magnetic-Reed-Switch Leads — The small, light-weight connections are reliable.

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Testing & Instrumentation

70 Measuring Conductor Widths and Spacings Electrically — The split cross-bridge resistor technique helps to verify microcircuit patterns. (Licensing Opportunity)

US Army Fact Sheet

Full-Wave Analysis of Isolated and Coupled Microwave Transmission Lines Using the Finite Element Method

The accurate prediction of the characteristic impedance, attenuation, coupling, crosstalk, etc., in microstrips, striplines and similar transmission lines is important in microwave and millimeter wave integrated circuits, digital circuit design, communication and other applications. The objective of a research effort was to consider microwave transmission lines with rather arbitrary configuration and to present a computer-aided analysis that allows simple and accurate calculation of its design parameters. The research developed a finite element approach to a hybrid-mode analysis of isolated and coupled microwave transmission lines. Both the first and higher-order ordinary elements, as well as singular and infinite elements, were used to solve for the eigenvalues and eigenvectors of the modes propagating along the line. Once the field distribution in the cross section of the line is known the characteristic impedance of the dominant mode propagating along the line can readily be obtained. A perturbational approach was developed for estimating the losses due to conductor and dielectric dissipation and computing the attenuation constant for each mode.

Lines treatable by this method may contain an arbitrary number of arbitrarily shaped conductors, including a system of conductors either placed above a single ground plane or between two parallel ground planes, and inhomogeneous dielectric regions that can be approximated locally by a number of homogeneous subregions.

The results obtained using the finite element procedure have been compared for various types of microwave transmission lines and have been found to agree well with available data.

FOR ADDITIONAL INFORMATION: A copy of the report is available from NTIS, Springfield, VA 22161; (703) 487-4600.

NTIS order number: AD-A178805/8/NAC

Price code: A03

NAVY
Domestic Technology Transfer Fact Sheet

Transmitting Antenna Arrays Adaptable

The Naval Ocean Systems Center has developed an adaptive system for transmitting a signal that may be used in low-power or high-power applications in conjunction with a commercial radio transmitter to optimize the radiation field of the transmitter used. Such technology could be useful in the broadcasting industry.

The transmitter generates a continuous-wave (CW) signal. This signal is split by a power divider circuit into two or more parts, depending upon how many antenna elements are used. Each part of the signal is then given amplitude and phase control, typically by using quadrature hybrid-attenuator and summer circuits. Each part of the signal, with individually controlled amplitude and phase, is then connected to one antenna element.

Linear amplifiers may be provided after the amplitude and phase control circuit in order to provide enough power for accurate readings of antenna current and field strength.

Critical monitoring points are selected in the direction of required antenna pattern nulls and/or in the directions of desired antenna pattern maximums. At each monitoring point, a signal strength measurement device is placed and a method for relaying this information to a microprocessor located at the transmitter site is required (either voice or telemetry).

The microprocessor, using the information from the monitoring points, adapts to provide optimum performance using a random search approach. Since the information from each monitoring point is separate, the random search algorithm can be required to either minimize or maximize the signal at each individual monitoring point depending upon whether a null or maximum is desired in that direction, that is, the direction from the transmitting antenna array to the monitoring point.

The number of iterations required will depend upon the number of array elements in the antenna, the number of monitoring points, and the starting point of the search. Using theoretical calculations, one may choose a reasonably close starting point; and convergence is generally quite rapid, certainly less than 100 iterations. If voice relay from the monitoring points and manual entry are used, the total time for initial convergence should be less than one hour; and, if a telemetry system were used, the whole process requires only a few minutes at most.

For Additional Information:

Backup material on this effort is available from:

Navy Domestic Technology Fact Sheet
Reader Reply Service
Code E211
Naval Surface Weapons Center
Dahlgren, VA 22448-5000
(703) 663-8921

Refer to 120601/TN

Segmented Waveguide Program for Long Wavelength Propagation Calculations

A model of longwave propagation developed at the Naval Ocean Systems Center (NOSC) is based on a waveguide mode formulation. To determine signal levels in this approach the basic problem is to obtain the model solutions to the specific waveguide under consideration, where complicated propagation paths are divided into horizontally homogeneous segments. The parameters of the segments are determined by the earth's ground conductivity, the magnitude and orientation of the geomagnetic field with respect to the direction of propagation, and the state of the ionosphere. Well-known computer programs which make the necessary calculations for a single set of propagation parameters are "WAVEGUID" (Pappert et al., 1970) and "MODESRCH" (Morfitt and Shellman, 1976). A new effort has modified WAVEGUID to supply calculations of long wavelength propagation along segmented propagation paths. This program is called the Segmented Waveguide (SW).

The computer program obtains waveguide mode solutions for very low frequencies and low frequencies (VLF/LF). The program allows for multiple homogeneous segments to be specified, allowing for consideration of variations in the earth-ionosphere waveguide. Path geometry and geophysical parameters can be computed by the program. Ionospheric disturbances due to man-made or naturally occurring events can also be modeled using the program.

Essential features of this program include:

- Automatic segmentation of the propagation path
- Allowance for presegmentation of the propagation path
- Allowance for variation of the ionosphere along that path

The program operates on propagation paths defined by a transmitter location and either a direction or a receiver location. A propagation path is defined as the great circle on a spherical earth. Variation of the geophysical parameters are to be expected along realistic paths. The diurnal condition in large part determines the significance of the other parameters. For instance, under daytime conditions the effect of variation of the geomagnetic field and for selecting the ground conductivity at any point on the earth's surface.

Each of the path segments is treated as a horizontally homogeneous planar waveguide. Earth curvature is introduced by use of a modified refractive index. A set of possible solutions to the waveguide mode equation must be input. Each of these solutions is processed by an iteration routine. Each iteration requires computation of ionospheric and ground reflection coefficients. Calculation of the ionospheric reflection coefficients requires integration of the coefficients through the ionosphere. An approximate formulation may be used which requires a secondary set of complex angles

be specified by the user. In that case, the ionospheric reflection coefficients are calculated for the secondary set of angles. These coefficients are used to interpolate the ionospheric reflection coefficients during the iteration of the primary set of possible solutions. This interpolation procedure requires much less computation time than does the more exact procedure.

The set of solutions for the first homogeneous segment must be input by the user. The program uses the results of up to three consecutive segments to extrapolate the solutions for successive segments. This reduces the number of iterations which are required for subsequent segments and allows for the tracing of mode solutions through a wide range of path variations.

The primary output of "SW" is data which may be used in mode summing programs. The strength of the electromagnetic field along the path can be obtained with either of two mode conversion models, one denoted "FULLMC" (Pappert and Shockey, 1972) and the other denoted "FASTMC" (Ferguson and Snyder, 1980). "FULLMC" does integrations through the ionosphere prior to calculating mode conversion coefficients and can be quite slow in execution time whereas "FASTMC" avoids the transionospheric integrations by use of approximations and runs quite quickly.

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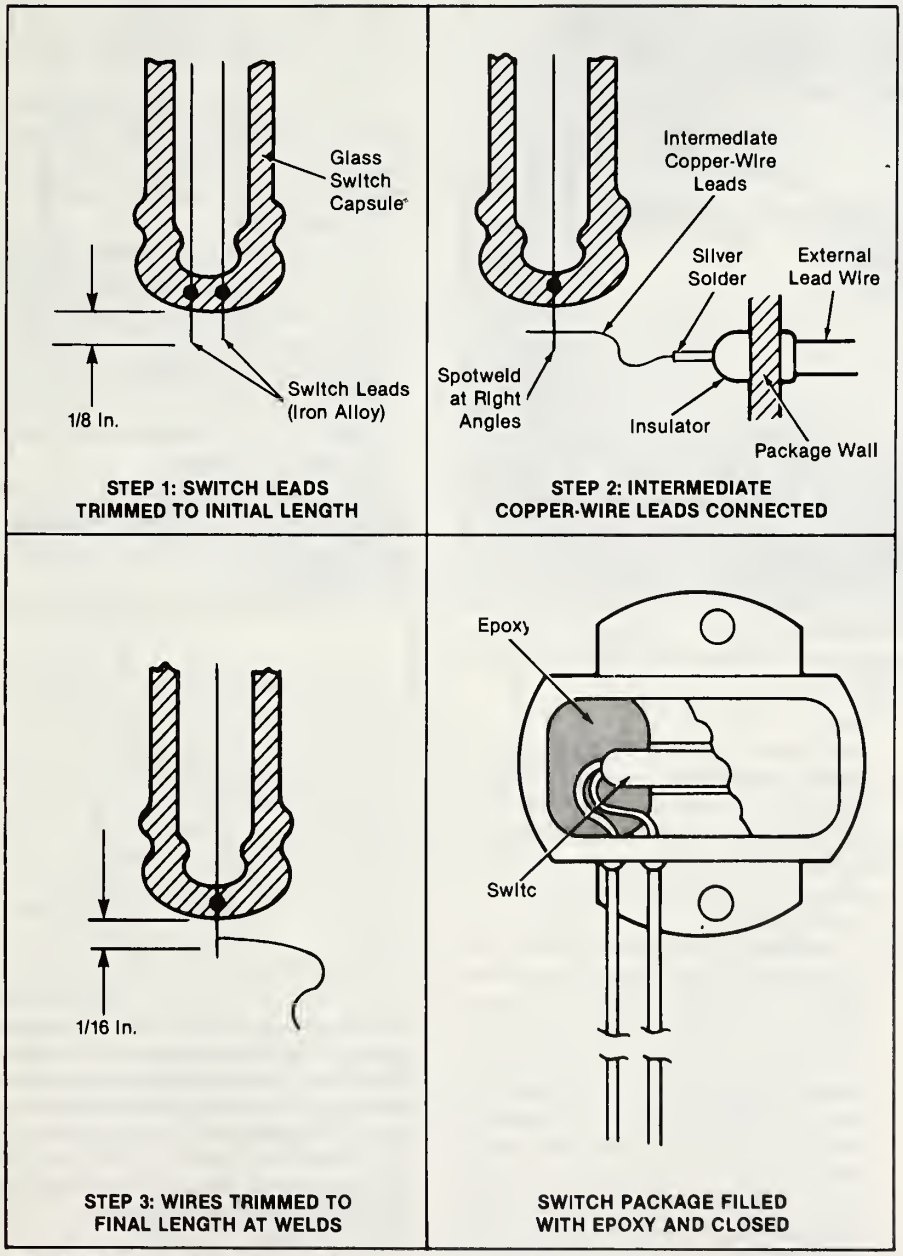
NASA Tech Brief
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center, Houston, Texas

Attaching Copper Wires to Magnetic-Reed-Switch Leads

The small, light-weight connections are reliable.

A bonding method reliably joins copper wires to short iron-alloy leads from a glass-encased dry magnetic-reed switch without disturbing the integrity of the glass-to-metal seal. The joint is resistant to high temperatures and has low electrical resistance.



Intermediate Copper Lead Wires connect the switch leads to external leads. The intermediate leads are spotwelded to the switch leads and silver soldered to the external leads.

First, the iron-alloy leads that protrude from the glass switch capsule (see figure) are trimmed to a length of 1/8 in. (3.2 mm). Next, one end of each copper wire is silver soldered to one of the external leads at the point where it enters the housing. The other end of each wire is spotwelded at a right angle to one of the iron-alloy switch leads. The switch leads are then trimmed to a final length of 1/16 in. (1.6 mm).

With the bonding method, a reed switch can be installed with a solenoid valve in a small, lightweight package. The switch provides an indication of the open or closed position of the valve.

This work was done by Rudolf Kamila of Consolidated Controls Corp. for **Johnson Space Center**. *No further documentation is available. MSC-20675 /TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD. 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THE ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Electronically Tuned Microwave Oscillator

Features include low phase noise and frequency stability.

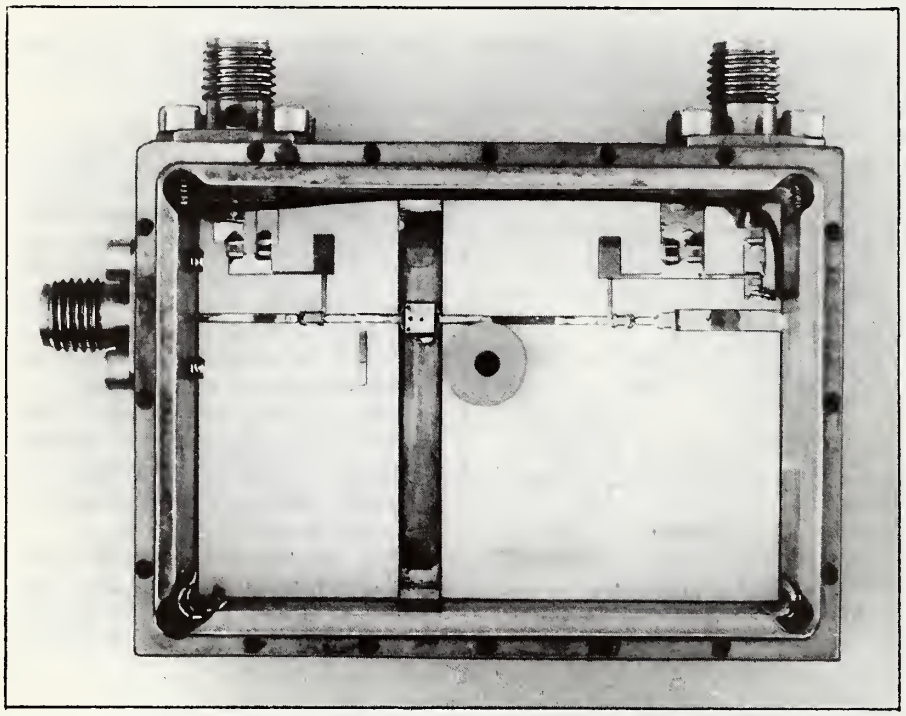


Figure 1. This **Electronically Tuned Microwave Oscillator** includes an npn bipolar transistor in a common-collector circuit as a negative-resistance device. The mechanically adjustable dielectric resonator enables a coarse frequency adjustment.

A bias-tuned, low-phase-noise microwave oscillator circuit is based on an npn bipolar transistor and a dielectric resonator. Operating at a frequency of about 8.4 GHz, the oscillator can be adjusted to give low phase noise, relatively flat power output versus frequency, and nearly linear frequency versus bias voltage.

The oscillator (see Figure 1) is laid out on an alumina substrate in a common-collector configuration to facilitate heat transfer from the transistor to the heat sink. The transistor is conservatively biased at about 60 percent of its rated voltage and current. The dielectric resonator is made of $(ZrSn)TiO_9$, which has a dielectric constant of 38 and an unloaded ratio of reactance to resistance (Q) of about 6,000 at 6 GHz. The resonator is placed on a 65-mil (1.65-mm) quartz spacer and coupled to the base microstrip line by placing it about a quarter wavelength from the transistor base terminal. The exact position has to be adjusted because it is critical in determining the Q under load, electronic tuning range, and the power output.

The resonator includes a mechanically adjustable metal tuning disk that provides a frequency adjustment of about 70 MHz per turn over the range of 8,387 to 8,601 MHz. Electronic tuning (see Figure 2) alters the transistor characteristics to provide a frequency adjustment, the characteristics of which depend on the resonator adjustments. For example, the resonator can be loaded to an estimated Q of 300 to provide about ± 1.75 MHz of nearly linear tuning on either side of a middle frequency of 8,417.75 MHz when V_{FC} is varied between −20 and +8 V. (The frequency sensitivity in this case is −125 kHz/V). The output power over this range varies less than 0.8 dB from a nominal level of −7.5 dBm. Similar results are obtained with a loaded Q of 500.

In the Q ≈ 300 condition, the single-sideband phase-noise spectral density (relative to the carrier power) at 1 KHz from the carrier was measured at −75.3 dB/Hz, −71.5 dB/Hz, and −71.2 dB/Hz at V_{FC} of −20, 0, and +8 V, respectively. Close to the carrier, there is a 30 dB/decade flicker frequency-modulated noise characteristic. The compromises among the dielectric-resonator, electronic-tuning, and phase-noise characteristics can be combined with temperature compensation to meet digital-radio requirements.

This work was done by Mysore Lakshminarayana of Caltech for **NASA's Jet Propulsion Laboratory**.

NPO-16836 /TN

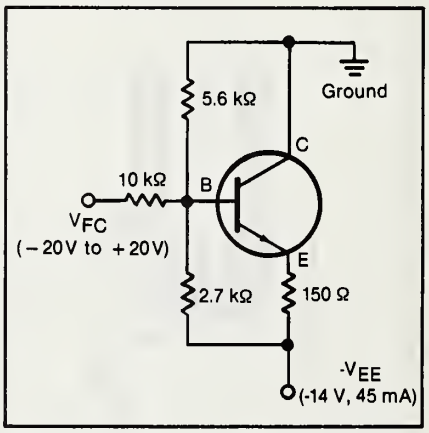


Figure 2. The **dc Component of the Transistor Base Voltage** is determined by the frequency-control voltage, V_{FC}, and the network of bias resistors. In combination with the dielectric-resonator adjustments, this bias network enables the oscillator frequency to vary nearly linearly with V_{FC}.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD. 21240; (301) 621-0100 Ext. 241*

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Highly Stable Microwave Resonator

Superconducting walls on a sapphire-filled cavity make a low-loss device.

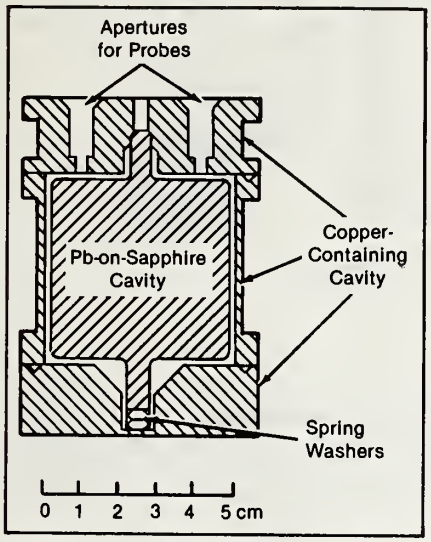
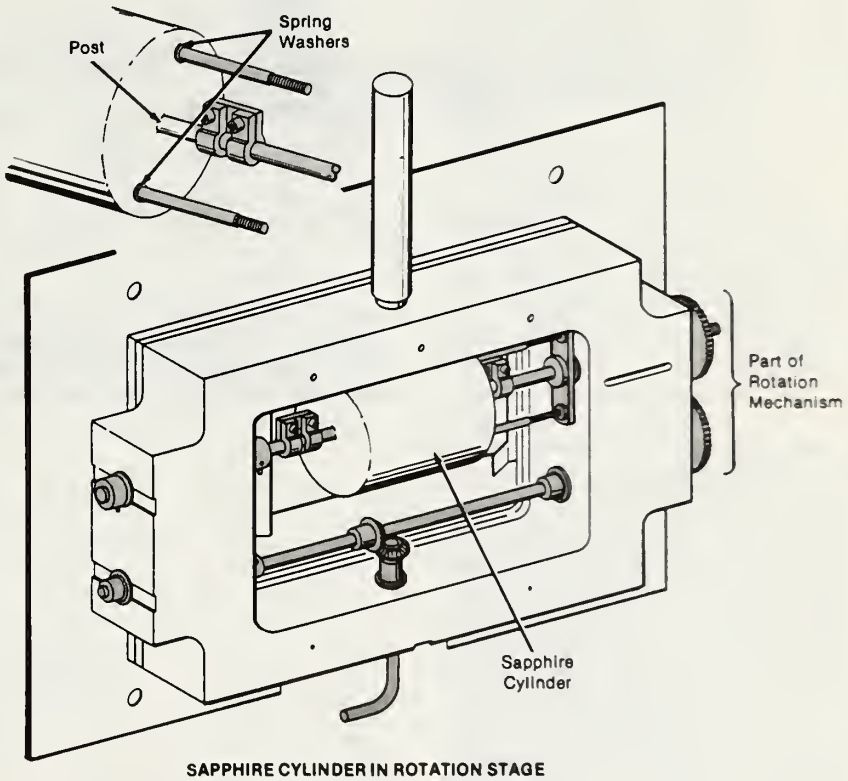


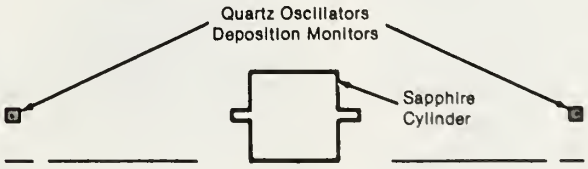
Figure 1. The **Lead-Coated Sapphire Cylinder** is mounted in a lead-plated copper-containing cavity, which is inserted in a bath of liquid helium. Microwave signals are transmitted into and out of the cylinder through the probe ports.

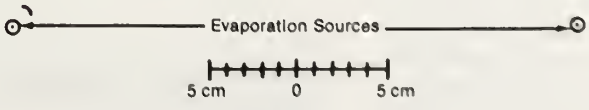
An improved microwave resonant cavity consists of a sapphire cylinder coated with a thin film of superconducting lead (see Figure 1). Operated well below the superconducting transition temperature at 1.5 K, the cavity demonstrated superior frequency stability and quality factor. The quality factor Q (a figure of merit equal to the ratio of reactance to resistance) is more than 2×10^9 in the TE_{011} mode at the resonant frequency of 2.689 GHz. The cavity frequency is highly stable and therefore this cavity is suitable for use in standard frequency generators and in filters.

The oscillator can be no more stable than the resonant frequency of its cavity.



SAPPHIRE CYLINDER IN ROTATION STAGE





COATING CONFIGURATION

Figure 2. A **Mechanism Turns the Sapphire Cylinder** while lead vapor condenses on it. Two sources of lead and controlled rotational speed ensure the uniform lead film thickness that is essential to the extraordinary performance of the cavity. Spring washers on rods prevent deposition on two circular apertures that will serve as the probe ports.

Therefore, dimensional stability is crucial to oscillator stability; the dimensional response to changes in temperature and to tilt with respect to gravity should be minimal. In the new cavity, the mechanical and thermal-expansion properties are those of sapphire, and the superconducting film serves as a low-loss cavity wall. The dimensions of the superconductor-on-sapphire cavity are distorted by temperature less than 1/100 as much as those of a bulk niobium cavity, and they respond to tilts less than 1/10 as much.

The sapphire is a right circular cylinder, with equal length and diameter of 4.82 cm. Axial posts extending from each end serve as supports. While the cylinder was rotated on its posts in a vacuum deposition system, a smooth, fault-free film of 99.9999-percent pure lead was evaporated from two molybdenum boats at 45° angles from the central plane of the cylinder (see Figure 2). The boats were connected in series with a power supply. The rates of evaporation were matched by adjustment of a shunt across one of the boats. The rates were monitored individually by deposition on a quartz oscillator directly above each boat. The cylinder was turned at 33 revolutions per minute and a uniform film of sufficient thickness was obtained after 10 minutes of evaporation.

The surface resistance of the lead film closely matches that predicted by theory. The residual resistance is small, indicating that losses at the lead/sapphire interface are quite small. Moreover, since most of the low loss can be accounted for by dissipation in the film, absorption in the sapphire is believed to be exceptionally low.

This work was done by Donald M. Strayer, Sarita Thakoor, G. John Dick, and James E. Mercereau of Caltech for **NASA's Jet Propulsion Laboratory**. *NPO-16663 /TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD. 21240; (301) 621-0100 Ext. 241*

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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Switching Circuit Regulates Solenoid Current

The efficiency is high, yet the ripple current is relatively low.

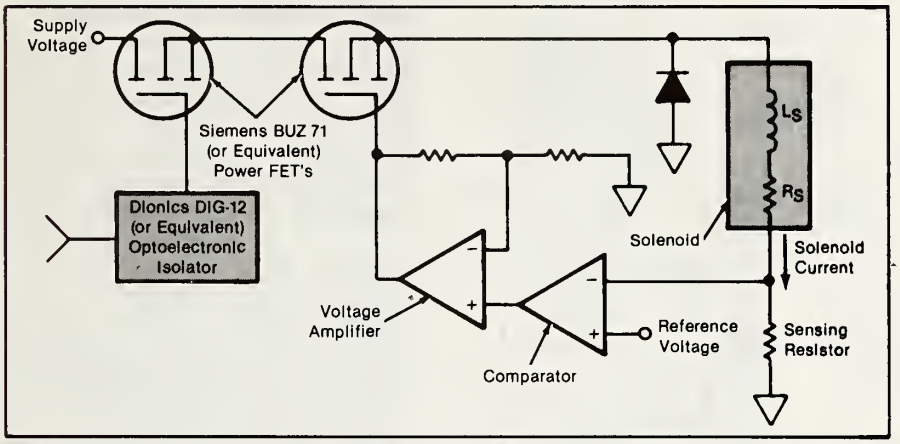

Figure 1. The **Switching Regulator** repeatedly causes the solenoid current to build up to a maximum level, then to decay to a minimum level: thus the current ripples about a commanded intermediate level. The FET's dissipate significant amounts of power only during the brief turn-on and turn-off intervals.

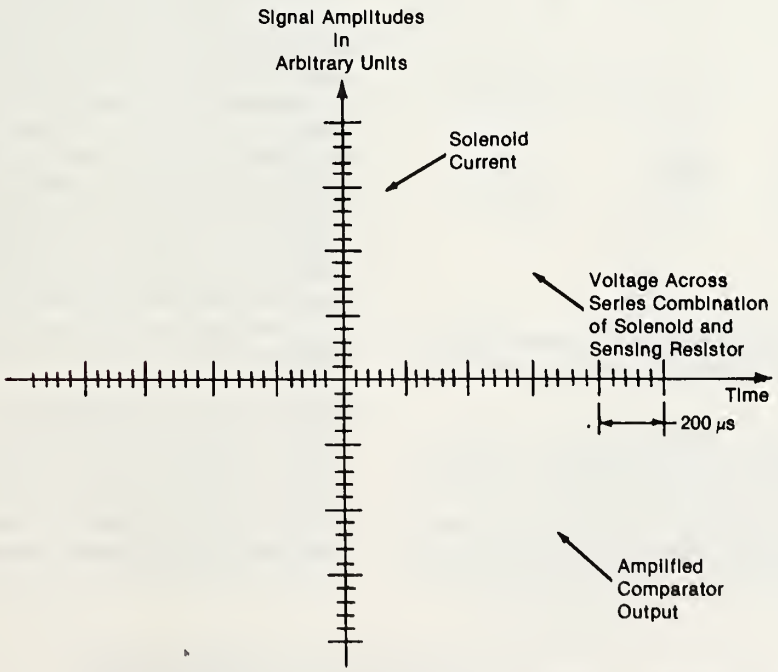

Figure 2. These **Oscilloscope Traces** (redrawn from a photograph for clarity) were taken from the circuit of Figure 1. These traces show the short turn-on and turn-off times that limit the power dissipation of the circuit.

By switching current pulses on and off, a circuit regulates the current in a solenoid valve. The regulation is independent of temperature. The switching regulator is much more efficient than the linear regulator it replaces, dissipating 0.075 watt versus 17.7 watts for the linear circuit. The new circuit requires no heat sink and is therefore more compact. Its parts cost no more than those of the linear regulator.

The solenoid current generates a voltage by passing through a sensing resistor (see Figure 1). This voltage is compared with a reference voltage that is proportional to the commanded solenoid current. The comparator produces a high or low voltage at its output terminal, depending on whether the sensed solenoid current is low or high, respectively.

The comparator output is amplified by a direct-coupled voltage amplifier and fed to a power field-effect transistor (FET). The FET accordingly turns the supply voltage to the solenoid on and off so that the solenoid magnetic field repeatedly builds up and collapses at a rate that tends to keep the solenoid current near the commanded value. A power diode clamps the flyback pulse and enables the continuation of the solenoid current during the decay period. In a laboratory version of the circuit, the solenoid current exhibited a 120-mA peak-to-peak ripple about the commanded dc value of 0.75 A, with a buildup time of about 600 μs and a decay time of about 320 μs (see Figure 2).

A remarkable feature of the type of power FET selected for the circuit is that it has an extremely low "on" resistance — no more than 0.1 ohm. This accounts in part for the low power dissipation of the circuit.

Another power FET of the same type is the master switch that connects the supply voltage to the circuit. It is turned on by a light pulse to a photovoltaic optoelectronic isolator. (The isolator acts as a floating voltage source, and the light pulse generates the voltage.) Since the power FET has an ample 8.2-ampere continuous

current rating, it can drive additional regulators in parallel. The combination of the power FET and isolator can also be used as an electronic relay.

This work was done by Richard A. Simon of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center
Refer to MFS-19904. /TN

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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Electronically Controlled Resistor Bank

Resistance is quickly varied in small steps over a wide range.

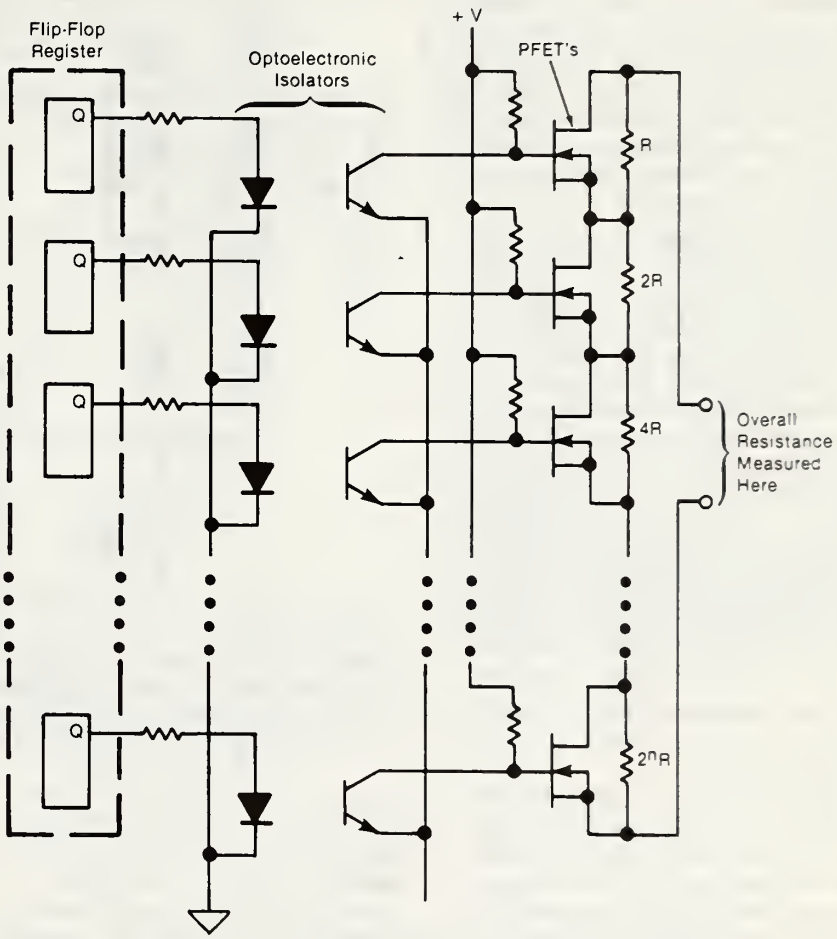
A device with no moving parts provides a variable electrical resistance. It can be used with analog or digital circuity to provide electronic selection of any of a large number of resistance values for testing, simulation, control, or other purposes. The nearest electromechanical equivalent of the all-electronic device is a potentiometer driven by a servomotor.

The device (see figure) includes n + 1 resistors connected in series, in a binary sequence of resistance values R, 2R, 4R, ... 2^nR. Each resistor is shunted by a power field-effect transistor (PFET), which has a low "on" resistance. The overall resistance of the chain of resistor/PFET pairs is controlled by using the PFET's to short out selected resistors.

The gate of each PFET is connected through an optoelectronic isolator to the output of one stage of a flip-flop register. When one bit of the register is set (according to its digital input), the register output switches to the state that turns off the associated PFET, thereby turning off the shunt around the corresponding resistor and adding its resistance to the series total.

The bits in the register are arranged in the same order as that of the resistors: the least significant bit controls the resistance R, while the most significant bit controls the resistance 2^nR. Thus, the overall resistance of the chain is determined by the binary word in the register and can be varied in steps of R from nearly zero — all PFET's on — to $(2^{n+1} - 1)R$ — all PFET's off.

The overall resistance changes almost instantaneously with a change in register contents. Therefore, the resistance can be varied as a function of time by sending a sequence of binary words to the register. The overall resistance can also be varied in response to a changing analog voltage; in this case, an analog-to-digital converter samples the analog voltage, and its output is fed to the register. A timing circuit frequently restarts the analog-to-digital conversion so that any change in the analog input is quickly reflected in a change of resistance.



Selected **Resistors in a Series Chain** are electronically shunted by PFET's to delete their values from the overall resistance of the chain.

This work was done by Walter L. Ross of Rockwell International Corp. for **Marshall Space Flight Center**. *MFS-29149 /TN*

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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Computerized Torque Control for Large dc Motors

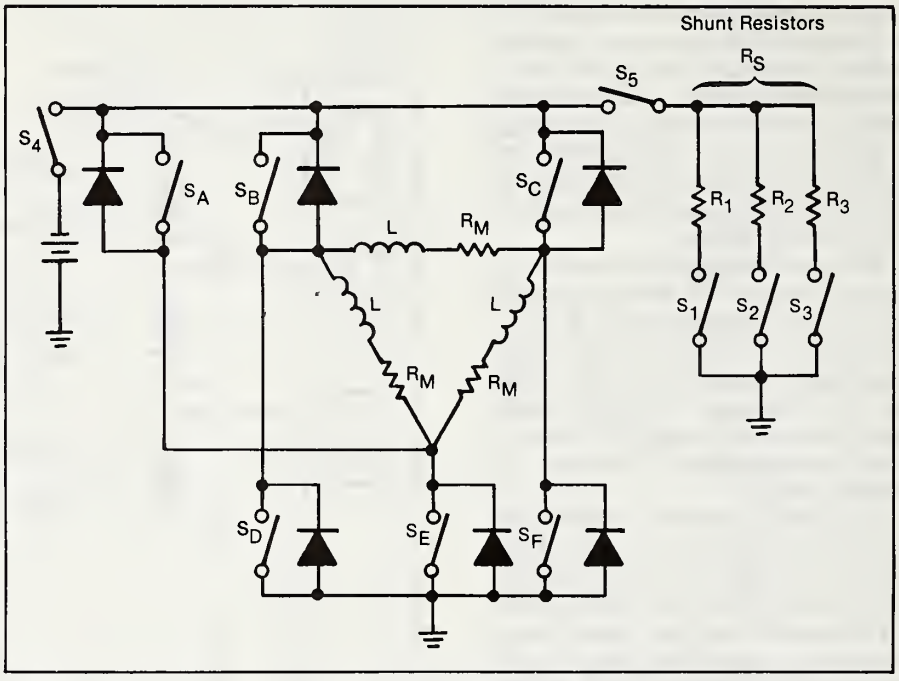
The speed and torque ranges in the generator mode are extended.

A system of shunt resistors, electronic switches, and pulse-width modulation controls the torque exerted by a large, three-phase, electronically commutated dc motor. The system is particularly useful for a motor operating in the generator mode because it extends the operating range to low torque and high speed.

In the motor mode, the power-supply switch (S_4) is closed, while the shunt-resistor switch (S_5) is open (see figure). As the shaft rotates, Hall-effect devices select pairs of switches that determine the current path through the windings. At any instant, one of the lower motor switches (S_D, S_E, or S_F) is closed, while one of the upper motor switches (S_A, S_B, or S_C) is driven on and off by a pulse-width modulation signal with a duty cycle controlled by a computer. When the upper motor switches are all open, the inductively driven, decaying current flows through one of the shunt diodes on one of the lower switches. The inductive/resistive time constant of the motor filters the current fluctuations, thereby smoothing out the torque fluctuations produced by switching.

At the transition to the generator mode, the duty cycle of all three upper motor switches goes to zero; that is, they remain open. The three lower switches continue to operate as before, with a duty cycle of 1. As the system goes deeper into the generator mode, the upper switches remain open, and the lower switches are alternately turned off for short periods; that is, they begin to operate at a duty cycle less than 1.

As in the motor mode, this duty cycle can be varied in the generator mode to control the torque. In the generator mode, S_4 is opened, and S_5 is closed to connect R_S, which is one of the shunt resistors R_1, R_2, or R_3. Analysis shows that for a sufficiently large inductive-decay time constant, the torque in the generator mode is given approximately by



The Shunt Resistor and the Motor-Switch Duty Cycle are selected by a computer (not shown) to obtain the desired motor torque and a safe voltage across the shunt resistor.

$$T = K_T V_B / [R_M + (1 - W)R_S]$$

where K_T = the torque-to-current ratio of the motor, V_B = the back electromotive force of the motor, R_M = the winding resistance, and W = the duty cycle.

Thus, the torque can be decreased by decreasing W or increasing R_S. However, one cannot arbitrarily select any combination of W and R_S: as the motor speed increases, V_B and the voltage across R_S also increase, and may become too large for the circuit to handle. When this occurs, a lower value of R_S must be selected. That is why S_1, S_2, and S_3 are provided to select different shunt resistances R_1, R_2, and R_3.

To maintain the continuity of torque while switching shunt resistors, the computer must adjust the duty cycle to maintain the continuity of $(1 - W)R_S$. For example, if the duty cycle is W_1 when operating with $R_S = R_1$, then the duty cycle must be changed to $W_2 = 1 + [(W_1 - 1)R_1/R_2]$ when the shunt resistor is changed to R_2. Such a calculation is needed only once each time the shunt resistor is changed.

This work was done by Richard M. Willett, Michael J. Carroll and Ronald V. Geiger of Martin Marietta Corp. for **Marshall Space Flight Center.**
MFS-28169 /TN

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NASA Tech Brief
National Aeronautics and Space Administration
Ames Research Center, Moffett Field, California

Licensing Opportunity

FM-to-Digital Converter

A circuit includes an array of low-cost multivibrators.

An inexpensive circuit converts a frequency-modulated (FM) signal into a digital signal. The circuit consists of a zero-crossing detector and a series of monostable multivibrators and D-type flip-flops (see Figure 1).

The zero crossings of the FM input are detected and converted to pulses at a voltage compatible with transistor/transistor logic. These pulses are fed to the monostable multivibrators and flip-flops. The positive-going edge of a pulse changes the output of a multivibrator from its normal 1 to a 0. The duration T_i of the 0 output of each multivibrator equals that of its predecessor in the chain minus a small decrement of time: $T_{i+1} = T_i - \Delta T$. In a chain of N monostable/D flip-flop pairs, T_1 is half the reciprocal of the lowest frequency to be detected, and T_N is half the reciprocal of the highest frequency to be detected.

When a multivibrator returns to its logic 1 state, it clocks the zero-crossing data from the input to the output of its flip-flop. If the duration of a zero-crossing pulse is shorter than the duration T_k of the logic 0 state of the kth multivibrator, a logic 0 will be clocked out of flip-flop D_k. If the zero-crossing pulse is longer than T_k, a logic 1 is clocked out of flip-flop D_k. In the example of Figure 2, the zero-crossing pulse is shorter than T_2 but longer than T_3, signifying a frequency somewhere between $1/(2T_2)$ and $1/(2T_3)$.

The pattern of 1's and 0's on the flip-flop outputs thus represents the input frequency. As the frequency increases, the zero-crossing pulses grow shorter and the pattern changes, as indicated in the truth table. The more multivibrators there are, the more patterns there will be and the more precisely the input frequency can be resolved.

The circuit might also be used to control a filter. As frequency changes are detected, the binary output could be fed to an attenuator or amplifier to reduce or

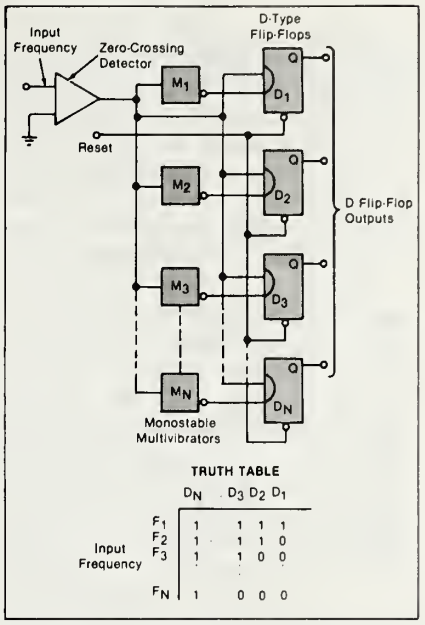

Figure 1. The **Pattern of Ones and Zeros** on the flip-flop outputs represents the input frequency. The truth table shows a pattern for four pairs of multivibrators; many more of these inexpensive chips could be used in a real circuit for greater resolution.

increase the gain; unwanted frequencies in a signal would thus be suppressed.

The multivibrator circuit offers important advantages over other ways of converting FM signals to binary signals. Compared with phase-locked loops and constant-energy, pulse averaging circuits, it has fewer components and responds more quickly.

This work was done by Michael Moniuszko of **Ames Research Center.** *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Council, Ames Research Center
Refer to ARC-11172/TN

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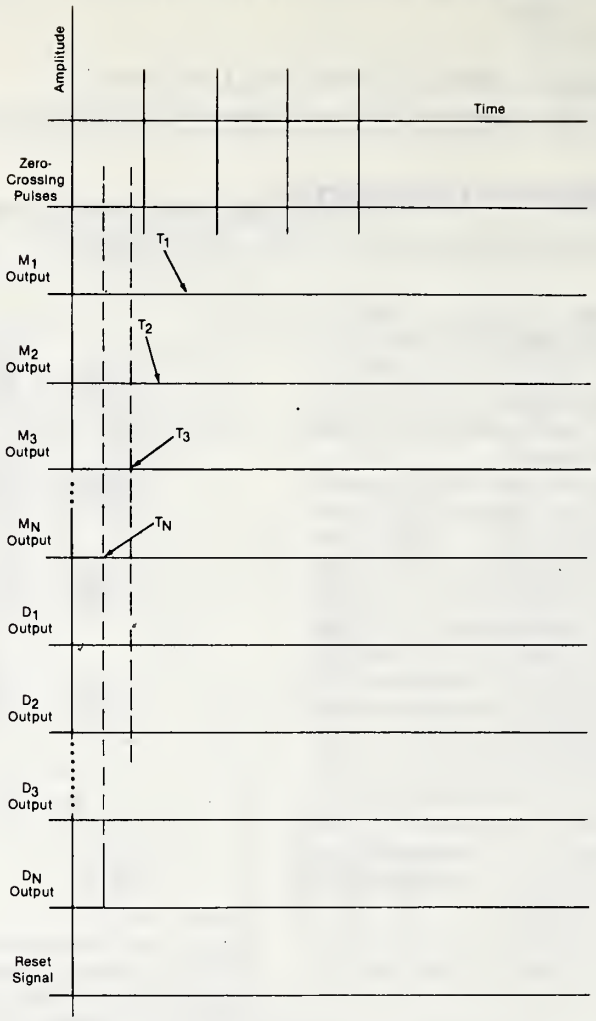

Figure 2. The **Timing Relationships** between the zero-crossing pulses and the logical-zero output intervals of the monostable multivibrators determine the pattern of ones and zeros at the outputs. Here, the frequency lies between $f_2 = 1/(2T_2)$ and $f_3 = 1/(2T_3)$.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD. 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Measuring Conductor Widths and Spacings Electrically

The split cross-bridge resistor technique helps to verify microcircuit patterns.

The widths and spacings of conductor lines on integrated circuits are measured electrically by the split cross-bridge resistor technique. Because this technique uses the same test equipment as the one used to characterize test transistors, it speeds the evaluation of integrated-circuit fabrication processes. When the measurement of probe currents and voltages and the reduction of the measurement data are automated, this test structure can be probed and characterized in less than one second. Thus, the structure can be examined quickly to verify adherence to design rules and thereby establish the difference between the linewidth and spacing of the integrated-circuit materials and those specified by the circuit designer.

The split cross-bridge resistor test pattern (see Figure 1) is fabricated by a photolithographic process. The parameters of interest are the sheet resistance, R_s, the linewidth, W, the space between the lines, S, and the line pitch, W + S. The structure can be designed so that W and S may have micrometer or submicrometer dimensions. It is also applicable in characterizing the larger lines and spaces found in printed-circuit boards.

The test structure is probed at the eight pads as shown, and the sheet resistance is calculated from the voltage V_a and the current I_a from

$$R_s = \pi V_a / I_a \ln 2$$

The line width and line spacing are calculated from voltage measurements V_b and V_c at taps separated by a distance L along the current-carrying channel. The current for these measurements is I_{bc}. The line width is calculated by

$$W = R_s L I_{bc} / (2V_c)$$

and the line spacing is calculated by

$$S = R_s L I_{bc} (V_c - V_b) / (V_b V_c)$$

Finally, the line pitch is calculated from P = W + S.

Figure 2 shows a cross section of the split portion of the structure formed in polycrystalline silicon and covered with silicon dioxide. The dimensions W_e and S_e of the polycrystalline conductor pattern are measured electrically as described above. Also indicated are the widths and spaces, W_p and S_p, on the photomask used to make the pattern, and W_v and S_v, the visual widths and spacings observed on the circuit. Provided that the features are not

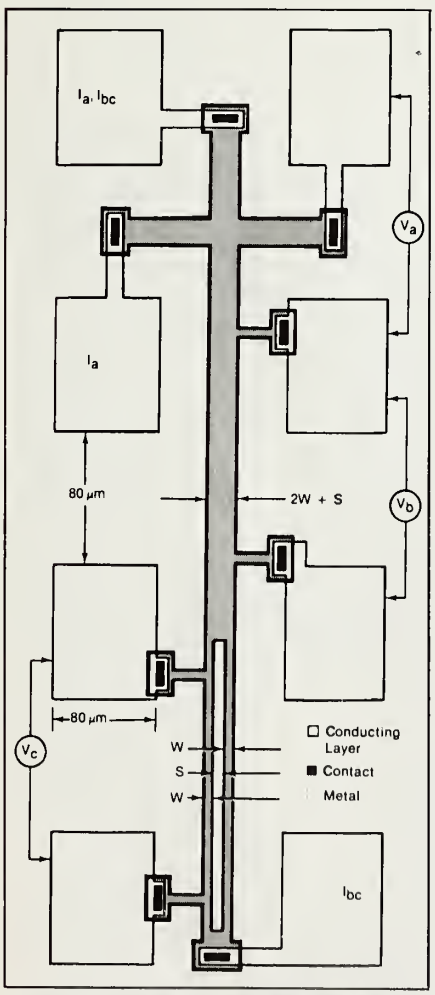

Figure 1. The **Split Cross-Bridge Resistor** is a test structure in a photofabricated single-layer conductor. Electrical measurements via the eight probe pads enable the deduction of critical circuit dimensions.

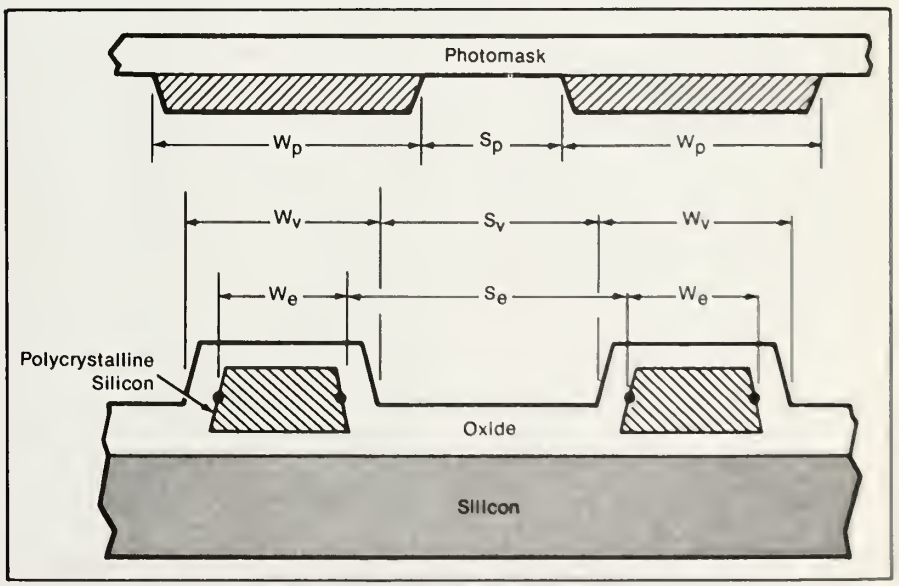

Figure 2. The **Photomask, Polysilicon Conductor, and Oxide Coating** have different line width and line spacings. The subscripts e, v, and p denote the electrical (polysilicon), visual (oxide), and photomask dimensions, respectively.

magnified during photofabrication, the photomask, visual, and electrical pitches must all equal the initial design value. This allows one to double check the electrical pitch value against the design value and thus provides measurement quality assurance. This test structure has been patented under U.S. Patent No. 4,516,071 (May 7, 1985).

This work was done by Martin G. Buehler of Caltech for **NASA's Jet Propulsion Laboratory**.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL Refer to NPO-16021/TN

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Energy

19 Thin Mirrors May Improve Outlook for Solar Electric Plants

20 Tailored Rubblizing May be Key to More Efficient Retorting

21 ZnSe Films in GaAs Solar Cells — ZeSe may increase efficiency and conserve material.

Thin Mirrors May Improve Outlook for Solar Electric Plants

Commercial power plants that generate electricity from solar energy may be a step closer to reality if new "stretched-membrane" heliostat mirrors work well in tests at Sandia National Laboratories.

Heliostats—large mirrors mounted on rotating, sun-tracking frames—collectively represent between one-third and two-thirds of the capital outlay for a solar central receiver power plant, so there is great interest in reducing their cost. Thousands of heliostats would be needed in a commercial-sized plant.

Computers and electric motors automatically keep heliostat mirrors pointed toward the sun during daylight hours. The mirrors reflect the sun's rays to a central tower several hundred feet above the ground, generating intense heat near 1,050°F. The heat is absorbed by a transfer fluid (water, molten salt, or sodium) that can be used to drive a generating turbine.

Solar energy researcher Daniel Alpert with one of the two heliostats using stretched-membrane mirrors that are being tested at Sandia's Central Receiver Test Facility south of Albuquerque.

Sandia solar researchers estimate that heliostats made from lightweight stretched-membrane mirrors would cost up to 25 percent less than conventional heliostats made from heavy glass mirrors.

Resembles giant embroidery hoop

Construction is simple. A thin metal membrane is stretched completely around and over both sides of a large, round metal ring that resembles a giant embroidery hoop. A silver polymer film is glued to the side that reflects sunlight to the central receiver.

Sandia is testing two working prototypes of the stretched-membrane mirror, one made of steel and the other of aluminum. Both membranes are just a few thousandths of an inch thick.

Successful technical demonstrations of solar central receivers have been done at Sandia's Central Receiver Test Facility (CRTF) south of Albuquerque and at the "Solar 1" pilot plant near Barstow, Calif. However, the high cost for heliostats and other components has been one factor in preventing the construction of commercial-scale plants.

Heliostats used in the CRTF and Solar 1 demonstration plants were made by attaching silvered-glass mirrors to a frame. The 1,818 heliostats at Solar 1 each contain 12 rectangular mirrors measuring 3-1/2 by 10 ft—a total of 420 ft^2 of reflecting surface.

Both stretched-membrane mirror prototypes are 26 ft across (about 530 ft^2) and are very light in weight. A membrane and support ring typically weigh about 2.2 lb/ft^2, compared to about 7.2 lb/ft^2 for a conventional glass mirror assembly.

Small pump focuses beam

The 6-in. space between the front and back membranes is airtight. The interior air pressure can be monitored by instruments and controlled automatically by a small, reversible pump. Normally, the pump maintains a slight partial vacuum to bring the centers of the front and back membranes about an inch closer together. This results in a slightly concave mirror surface that reflects a tightly focused beam to the receiver.

The prototype stretched-membrane mirrors were

designed and built by private firms working under contract to Sandia. Science Applications International Corporation of San Diego, Calif., made the one using a steel membrane, and Solar Kinetics, Inc., of Dallas, Tex., made the aluminum-membrane mirror.

Both prototypes are undergoing a series of tests at the CRTF to determine how well they work, how well they hold up over time, and what improvements are needed. These tests are scheduled to be completed by mid 1988.

Daniel Alpert of the Central Receiver Technology Division leads the testing and evaluation effort. He says the high capital cost for a solar central receiver plant makes it vital that heliostats be rugged and reliable.

"If either or both of the 26-ft stretched-membrane heliostats work as well as hoped, we plan to build and test larger 'next-generation' versions," Alpert says. He thinks a 50-ft-diameter mirror may be about optimum for commercial power plants if the concept proves workable.

Most of Sandia's planning and design work on stretched membranes was conducted or coordinated by personnel at its Livermore, Calif., facility. Thomas Brumleve (now retired), former stretched-membrane project leader there, is credited with many of the ideas that are incorporated into the prototypes.

Should improve outlook

Clayton Mavis, the current project leader at Livermore, believes reliable and cheaper stretched-membrane mirrors will greatly improve the outlook for solar central receiver power plants. However, he acknowledges that other components also need improvements and that the energy supply, demand, and price situations must change before solar electric plants are built.

Mavis says, "For central receiver plants to be economically feasible, the demand for electricity will have to increase and fossil fuel prices will have to be higher. No one knows for sure if or when these events will occur, but we want to make sure we have the best possible solar technology ready when it is needed."

Research done at the Solar Energy Research Institute (SERI) in Golden, Colo., has also contributed to this project. Analytical and laboratory-scale studies done by SERI researchers have helped Sandia personnel in their selection of materials and structures.

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Refer to announcement 22, No. 6

Tailored Rubblizing May Be Key to More Efficient Retorting

Sandia National Laboratories has demonstrated how it may be possible to significantly increase the amount of oil that can be recovered during underground processing of oil shale rock.

When heated under proper conditions in a process called *in situ* retorting, oil shale yields a liquid that, although different in some respects from conventional petroleum, can be refined into most petroleum products.

The key is a new approach to carrying out the required oil shale bed preparation before retorting begins. Bed preparation involves fracturing (or rubblizing) the oil shale rock with explosives so that air can flow through it, permitting the thermally driven chemical reaction to occur.

Sandia's "second-generation *in situ* oil shale retorting" approach does not demand that bed preparation produce uniform rubble size and void space. Previously these two traits were thought to be required for efficient recovery of oil. Results from Sandia's laboratory experiments, coupled with computer simulations of transport processes, have led to the concept of tailoring the rock fracture process.

"Our studies can play a major role in determining the technology paths that energy companies will find most attractive when the price of oil rises again—as it almost surely will—and accompanying concerns about finding replacements for this diminishing resource return to the forefront," says Paul Hommert, supervisor of Sandia's Advanced Technology Division.

Up to 60% higher yield

The Sandia research, begun in 1981, indicates that use of the new bed preparation approach could yield 30 to 60 percent more oil per operation than was previously thought to be possible. This would be accomplished by minimizing yield losses—oil that is chemically freed from the rock, but which burns up before it can be recovered.

The new approach relies on a more complete application of known fluid dynamics principles to the complex retorting process.

Thomas Bickel, Sandia's oil shale project leader, explains, "The objective of bed preparation has always been to produce uniform, non-overlapping retort and combustion fronts. This proved to be very difficult to achieve in the field, however.

"Now, our research shows that alternative design approaches can produce beds that yield uniform fronts. The alternatives also provide considerably more bed preparation flexibility, which should translate into a higher likelihood of success in the field," Bickel says.

The Sandia approach can account for the inevitable variations in void that will be produced in a given blast, and leads to a designed variation in explosive loadings during bed preparation.

"As a result of the detailed laboratory studies of rubble bed flows that accompanied our experiments," Bickel says, "we can confidently prescribe how the particle size should be varied to ensure the correct flow through shale zones of differing void."

Companion work at Sandia is leading to validated computer models that will predict fragment size as a function of explosive loading.

Sandia's responsibility during first-generation retorting field demonstrations of the '70s and early '80s was exhaustive instrumentation, followed by analysis. This provided some vital understanding about the complex processes that were occurring.

More space in outer region

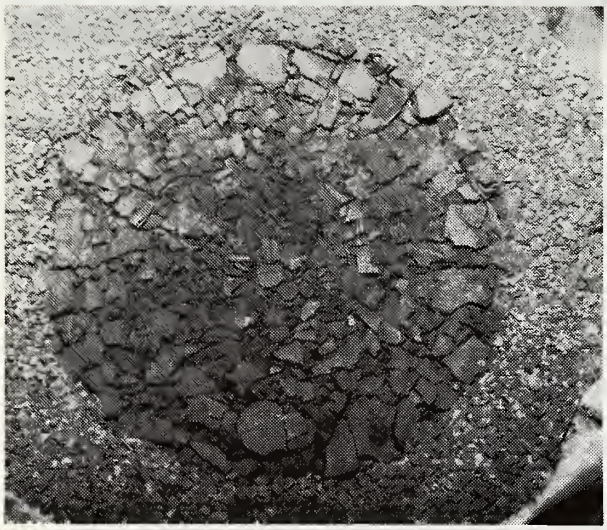
For instance, although explosive rubblization of the shale generally created uniform particle size as desired, the outer 10 percent of the retort, near the vertical walls, typically contained twice as much void space as the inner region, an undesired feature that designers couldn't seem to eliminate.

In such beds, the combustion and retort fronts traveled at different speeds and actually overlapped, a phenomenon that had a surprisingly dramatic and negative impact on the retort operation. It caused portions of the oil to burn up before it had a chance to be recovered. This overlap, Sandia lab work confirmed, occurred because the retorting front speed is directly proportional to the amount of air (gas flux) that can flow through a given volume of oil shale to fuel combustion.

"Because the outer regions of retort zones had more void space, they had a greater gas flux than inner regions," Bickel says. "Therefore, retorts progressed more rapidly in the outer zones. When the combustion front of the outer zone came too close to the retorting front of the inner zone, the liquid product burned preferentially instead of the nearby char."

Bickel's most recent laboratory work—conducted in a 3-ft-tall, 1-ft-diameter test vessel that holds more than 200 lb of oil shale—demonstrated that "we have achieved the necessary fluid dynamics and retorting process understanding to design a 'second-generation' retort," he said.

Bickel measured gas flux as a function of bed properties—void space, particle size, and particle shape.



This photo details the particle size contrast between inner and outer oil shale zones of a laboratory-scale experiment that demonstrated the feasibility of Sandia's second generation *in situ* oil shale retorting concept.

Particle shape is important because irregularly shaped particles in a bed decrease gas flux.

Next, based on results of the shale/gas flux studies, he formed a test bed with inner and outer zones of dramatically different rubble size and void space, but with what he believed would be identical retorting front velocities.

The outer section had 44 percent void space. The inner section had 25 percent void, but rubble that averaged 3 1/2 times larger in diameter than rubble in the outer section.

"Because of this preparatory work and the fluid dynamics understanding applied to the problem, we produced two distinct zones with different permeabilities," Bickel says. "However, the relationship of the permeability and void was such that the retorting front traveled through each at the same speed, and yield losses were significantly reduced."

Hommert concludes that the possibilities offered by the second-generation bed preparation approach, combined with the amount of oil recovered in Bickel's laboratory experiments, "call into question conventional wisdom that the maximum yield possible from *in situ* processing is 50 to 60 percent. With optimum bed preparation, yields as high as 80 to 90 percent may be possible."

FOR ADDITIONAL INFORMATION

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Refer to announcement 22, No. 6

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

ZnSe Films in GaAs Solar Cells

ZnSe may increase efficiency and conserve material.

Two proposed uses of zinc selenide films promise to boost the performance and reduce the cost of gallium arsenide solar cells. According to the proposal, ZnSe can serve as a surface-passivation layer and as a sacrificial layer that would enable the repeated use of a costly GaAs substrate in fabrication.

Currently, a GaAs cell is passivated by growing a 300-nm film of aluminum gallium arsenide on the front surface. A film of the approximate composition $Al_{0.8}Ga_{0.2}As$ is formed by metalorganic chemical-vapor deposition or by liquid-phase epitaxy at temperatures between 700 and 800 °C. However, the film gradually deteriorates under the influence of moisture and oxygen. It becomes difficult to form a stable, reproducible, low-resistance contact on the surface. In some cases, a thin oxide surface layer caused by prolonged exposure to air may not be optically compatible with various antireflective coating materials. Moreover, etching the oxidized surface may alter the optical properties of the underlying material.

The substitution of ZnSe for $Al_{0.8}Ga_{0.2}As$ would overcome these disadvantages. The lattice structure of ZnSe matches that of the GaAs substrate. The ZnSe is expected to passivate effectively while enabling a low-resistance contact to be formed. The dark saturation current should be reduced and the open-circuit voltage increased, and the cell efficiency should rise as a result. A further benefit is that the refractive index of ZnSe is substantially smaller than that of GaAs — 2.9 versus 3.4. Thus, the ZnSe film would reduce reflection from the cell, and it might not be imperative to apply an antireflective coating in a separate step.

Zinc and selenium are already used as dopants in GaAs solar cells. The same chemical-vapor-deposition apparatus now used to dope the cells with zinc and selenium could be used to form the ZnSe layer as well.

The close match of the crystal structures of ZnSe and GaAs would be further exploited in the other proposed application — using ZnSe as a preparation layer. A thin film of ZnSe would be applied to the GaAs substrate. Layers of n-type and p-type GaAs would be deposited on the ZnSe film, forming the active region of the solar cell.

At this point, the entire cell would be dipped in a 60-percent nitric acid solution. Only the ZnSe layer would dissolve, freeing the active GaAs region from the GaAs substrate. (Alternatively, the ZnSe could be etched away photochemically.)

Consisting only of the active region, the resulting solar cell would be ultrathin and ultralight. A new substrate would not be required for each cell; the same substrate would be used repeatedly as the base for the fabrication of the active regions of many cells. Only about 10 to 15 μm at the surface of the substrate would have to be removed after each use to restore its condition.

This work was done by Ram H. Kachare of Caltech for **NASA's Jet Propulsion Laboratory**. *NPO-16900 /TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD. 21240; (301) 621-0100 Ext. 241*
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0021

Engineering

22 Voluntary Standardization, Product Certification, and Laboratory Accreditation Programs

23 Comparing Test Data on Scale-Model Helicopter Rotors — Hovering data correlate well, but forward-flight data do not. (Licensing Opportunity)

24 Reduction of Orifice-Induced Pressure Errors — Porous plugs are placed in the orifices. (Licensing Opportunity)

25 Heater for Combustible-Gas Tanks — Heat is transferred safely through liquid metal.

26 Vibration-Free Vanes Direct Cryogenic Flow — An upstream fluid-dynamic surface prevents oscillations.

27 Mechanism Connects and Disconnects Lines Remotely — Misaligned, widely separated connector halves can be joined, then separated when necessary, while a human operator remains at a distance.

Software

28 Computerized Evaluation of Utility Plans

29 Integrated Analysis Capability Program — An interactive program assists in the design of large structures.

30 Expert System for Automated Design Synthesis — Engineers are assisted in searching for optimum solutions.

Testing & Instrumentation

31 Six-Axis Superconducting Accelerometer — Sensitivity and short-term stability are high. (Licensing Opportunity)

32 Measuring Leakage in a Pressurized-Fluid Loop — The technique can be applied to systems with inaccessible parts and connections. (Licensing Opportunity)

Other items of Interest

3 Easy Way to Automate Irrigation Valves (Licensing Opportunity)

NBS technology update

National Bureau of Standards
U.S. Department of Commerce
Gaithersburg, MD 20899

Voluntary Standardization, Product Certification, and Laboratory Accreditation Programs

The ABC's of Standards-Related Activities in the United States (NBSIR 87-3576) is an introduction to voluntary standardization, product certification and laboratory accreditation programs in the United States. The report is designed to provide information for users who may not be familiar with various areas of standardization and the relationships between groups. Information is provided on the history of standardization, types of standards, private standards groups in the U.S., standards development procedures, and the benefits and problems of standardization such as participation in the standards process by qualified consumer representatives.

For Additional Information:

For copies of *The ABC's of Standards-Related Activities in the United States* NBSIR 87-3576, send a self-addressed mailing label to: Maureen A. Breitenberg, A629 Administration Building, National Bureau of Standards, Gaithersburg, Md. 20899; 301/975-4031.

0022

NASA Tech Brief
National Aeronautics and Space Administration

Licensing Opportunity

Comparing Test Data on Scale-Model Helicopter Rotors

Hovering data correlate well, but forward-flight data do not.

A report compares the acoustics and performance of a small-scale helicopter rotor with those of a full-scale rotor in both hovering and forward flight. A 2.1-m-dia, 1/6-scale replica of a main rotor was tested at a hover flight condition in the 40- by 80-ft (12- by 24-m) wind tunnel. Subsequently, the replica was tested in forward flight in a 7- by 10-ft (2- by 3-m) wind tunnel. For comparison, data were taken from previous full-scale tests.

In the hovering test, the performance and acoustic results for the model-scale and full-scale rotors agreed well. The expected influence of the Reynolds number on the profile power was evident. Acoustic low-frequency harmonic levels were found to scale geometrically. At full-scale mid-range frequencies, acoustic spectral levels rolled off more rapidly for the full-scale rotor than for the model. In forward flight, however, acoustics of the small-scale rotor compared poorly with the full-scale data. The acoustic spectra of both the model-and full-scale rotors showed similar trends, but the overall difference in levels was large, ranging from 5 to 10 dB.

This work was done by Cahit Kitaplioglu and Patrick Shinoda of **Ames Research Center**. *Further information may be found in NASA TM-86786 [ADA-165948] [A03] "Hover and Forward Flight Acoustics and Performance of a Small-Scale Helicopter Rotor System."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161,

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NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Licensing Opportunity

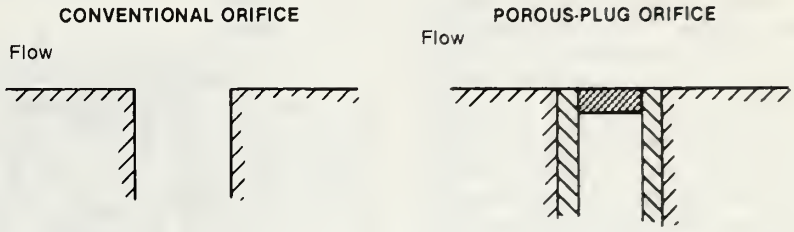
Reduction of Orifice-Induced Pressure Errors

Porous plugs are placed in the orifices.

The use of a porous-plug orifice reduces or eliminates errors, induced by the orifice itself, in measuring static pressure on an airfoil surface in wind-tunnel experiments. A piece of sintered metal is press-fitted into a static-pressure orifice so that it matches the surface contour of the model. The use of the porous material reduces the orifice-induced pressure error associated with a conventional orifice of the same or smaller diameter. The porous-plug orifice also reduces or eliminates any additional errors in the pressure measurement caused by orifice imperfections.

In wind-tunnel experiments, open holes drilled normal to the model surface have been the conventional means used to measure static pressure. To achieve the best result, these orifices must be perfectly round, square edged, and clean. In a high-Reynolds-number facility, the model boundary layer can be an order of magnitude thinner than the boundary layer in a conventional tunnel. For the effects of orifice-induced pressure error to be small under these conditions, the static-pressure orifices need to be very small — 0.010-in. (0.25-mm) diameter is generally used.

The fabrication of such small orifices with no imperfections is difficult. The combined effects of the flow turning into the orifice and a pitot effect, in which the flow stagnates at the downstream edge of the orifice, combine to produce a measured pressure that is inaccurately high. Furthermore, orifice imperfections cause the error in a conventional orfice to be even larger.



The **Flush-Mounted, Sintered-Metal Plug** reduces or eliminates the causes of orifice-induced errors.

The porous-plug orifice (see figure) prevents the flow from turning into the orifice, thereby reducing or eliminating the orifice-induced pressure error. Also, since the flush-mounted, sintered-metal plug smooths the airfoil surface, the error introduced by imperfections in the orifice is eliminated.

This concept was tested on an airfoil in the Langley Research Center 0.3-m Transonic Cryogenic Tunnel at chord Reynolds numbers up to 40×10^6. The pressures obtained using the porous-plug orifices were compared to those obtained using conventional orifices 0.010 in. (0.25 mm) in diameter, and results confirm that the use of the porous-plug orifice provides more accurate measurements in regions with very thin boundary layers.

This work was done by Elizabeth B. Plentovich, Blair B. Gloss, John W. Eves and John P. Stack of **Langley Research Center**. *Further information may be found in NASA TP-2537 [N86-20351/NSP]. [A03]*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel. Langley Research Center Refer to LAR-13569. /TN

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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

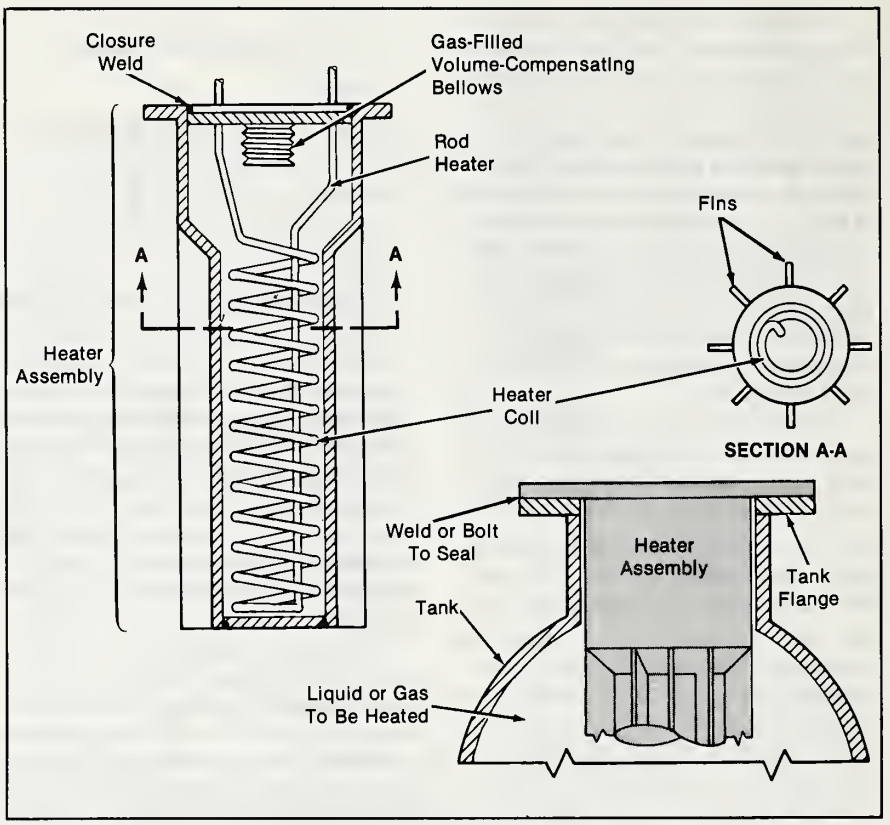
Heater for Combustible-Gas Tanks

Heat is transferred safely through liquid metal.

A proposed heater for pressurizing hydrogen, oxygen, or another combustible liquid or gas would be sealed in an immersion cup in the pressurized tank. The heater would be safer than the usual direct-contact heater because it would not be exposed directly to the liquid or gas. Because it can be safely operated at a higher skin temperature than can a conventional, directly exposed internal heater, it can be made smaller and lighter. It can be completely tested as an assembly before installation and can be removed from the tank as an assembly if necessary.

The heater would include a coiled rod-type resistance element in the stainless-steel immersion cup (see figure). The cup would be designed to be as strong as or stronger than the propellant tank. The coiled element would be supported in a bath of low-melting alloy; for example, of Bi with Pb, Sn, Cd, In, and/or Sb. The molten alloy would carry heat from the heating rod to the cup efficiently and help to prevent hot spots on the rod. A gas-filled bellows at the top of the sealed cup would compensate for volume changes in the alloy.

This work was done by Walter B. Ingle of Rockwell International Corp. for **Marshall Space Flight Center**. *No further information is available. MFS-29155 /TN*



Firmly Supported in a Finned Cup, a coiled rod transfers heat through liquid metal to a gas tank. The heater assembly can be welded or bolted to the tank flange.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD. 21240; (301) 621-0100 Ext. 241*

REFER TO THE NUMBER LISTED AT THE END OF THE ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Vibration-Free Vanes Direct Cryogenic Flow

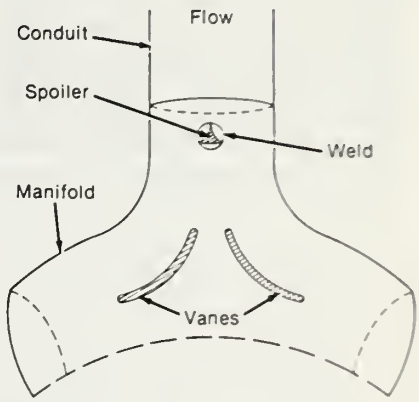
An upstream fluid-dynamic surface prevents oscillations.

A simple structural addition to a liquid-oxygen manifold prevents vibration and allows increased flow. A spoiler is placed in the liquid-oxygen conduit, just upstream from the manifold entrance (see figure).

The spoiler reduces the load at the leading edges of the distribution vanes in the manifold by altering the angle at which the oxygen stream impinges on the vanes. As a result, the center of pressure on each vane is moved toward its torsional elastic axis.

Without the spoiler, the vanes vibrate strongly at a frequency of about 4 kHz. With the spoiler, vibration is eliminated, even when the liquid-oxygen flow is increased considerably.

The spoiler, a specially shaped bar that spans the liquid-oxygen conduit, is introduced through holes drilled in the conduit and supported in the holes. After the spoiler has been installed, the holes are closed by welding. This mounting is sufficiently rigid that the spoiler itself does not vibrate in the flow.



A **T-Shaped Manifold** uses vanes to distribute liquid oxygen. Although far from the vanes, a spoiler suppresses vibrations caused by unstable dynamic coupling between the flow and the elasticity of the vanes.

This work was done by Gadicherla V. R. Rao of Rockwell International Corp. for **Marshall Space Flight Center**. *No further information is available. MFS-29180 /TN*

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NASA Tech Brief
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center, Houston, Texas

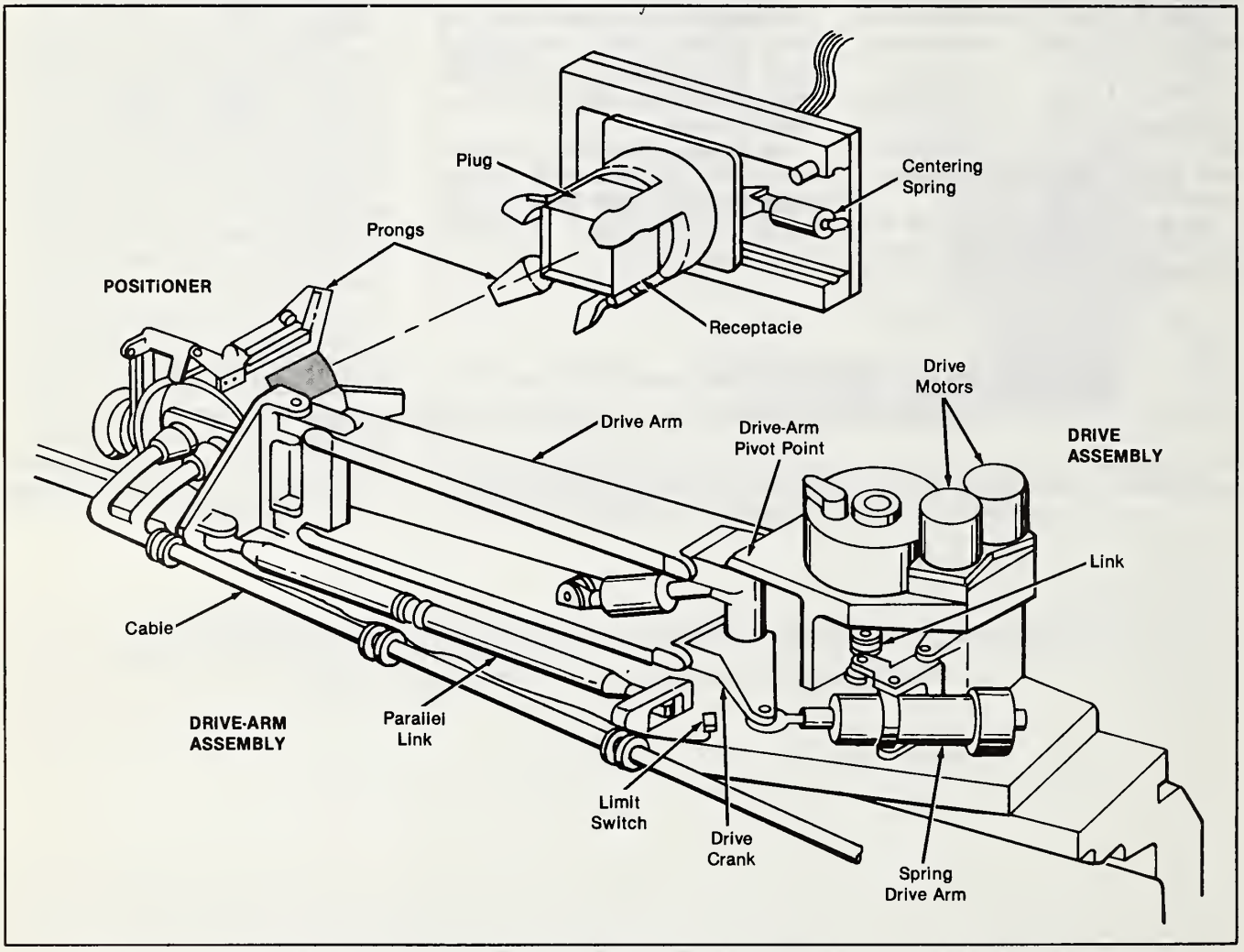
Mechanism Connects and Disconnects Lines Remotely

Misaligned, widely separated connector halves can be joined, then separated when necessary, while a human operator remains at a distance.

A mechanism connects and disconnects electrical, gas, or liquid lines by remote control. Developed for making (and breaking) electrical connections from the Space Shuttle orbiter to a payload during deployment or retrieval, the mechanism may also be adapted for use in areas inaccessible or hazardous to humans — underwater or in nuclear or chemical plants, for example.

Half of the connector — the plug half in an electrical connector — is mounted on the payload. The other half — the receptacle — is mounted on the positioner at the end of a pivoted drive-arm assembly (see figure). The drive assembly brings the positioner close to the payload connector half. The positioner then provides the adjusting movements necessary to align the connector halves and engage the pins. Meshing prongs on the plug and the receptable help to guide the mating parts.

This work was done by Victor Strand and Earl V. Holman of Rockwell International Corp. for **Johnson Space Center**. *For further information, MSC-21086 /TN*



The **Remote-Connection Mechanism** accommodates large displacements and misalignments of the plug and the receptacle.

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US Army Corps of Engineers

Fact Sheet

Construction Engineering Research Laboratory

Computerized Evaluation of Utility Plans

In the past, because of the extensive engineering calculations involved, the adequacy of existing stormwater and sewage systems at a potential construction site was not thoroughly determined until after the site had been selected. Unfortunately, this often led to unplanned expenses when existing systems proved incapable of accommodating the new utility demands. Occasionally, these additional expenses even exceeded the total budget for a project.

The Technology

The U.S. Army Construction Engineering Research Laboratory (USA-CERL) has developed the Computerized Evaluation of Utility Plans (CEUP). CEUP consists of two separate computer programs that analyze the sanitary sewerage collection and storm drainage systems on military installations for their adequacy in supporting future construction and base mobilization requirements.

Two types of information must be supplied by the user: a data base containing accurate descriptions of the physical characteristics of the components of each utility system, and estimated utility requirements (or appropriate substitute information such as serviced areas) at points throughout the system. For Army installations, the data base information can be obtained from Installation Basic Information Maps. However, in most cases it must be supplemented by field checks for verification and updating.

The programs enable users to determine what modifications need to be made to existing utility systems to meet future requirements.

Status

The programs are written in FORTRAN 77 and can be adapted for use on any mainframe computer. Versions of the two programs have been developed for use on microcomputers (MS-DOS, PC-DOS) having a minimum of 256 kilobytes of random access memory and a 8087 math microprocessor. The sanitary sewer distribution program is designed for either batch or interactive use; the storm sewer program is only a batch program

Numerous copies of the programs have been distributed to military and nonmilitary users. Copies of the two programs are available to nonmilitary users from the American Public Works Association.

FOR FURTHER INFORMATION CONTACT:

Michael Golish
Army Corps of Engineers, Construction Engineering Research Laboratory, P.O. Box 4005, Champaign, IL 61820
217-373-7270 or toll-free 800-USA-CERL (Outside Illinois), 800-252-7122 (Within Illinois).

Contact for private sector users is Mr. Richard Sullivan of APWA, 1313 E. 60th Street, Chicago, Illinois 60637, 312-667-2200.

NASA Tech Brief
National Aeronautics and Space Administration

Integrated Analysis Capability Program

An interactive program assists in the design of large structures.

The objective of the Integrated Analysis Capability (IAC) software system is to provide a highly effective, interactive analysis tool for the integrated design of large structures. IAC was developed to serve as an interface for programs from the fields of structures, thermodynamics, controls, and system dynamics with an executive system and data base to yield a highly-efficient multidisciplinary system.

Special attention is given to such user requirements as data handling and online assistance with operational features and the ability to add new modules of the user's choice at a future date. IAC contains an executive system, a data base, general utilities, interfaces to various engineering programs, and a framework for building interfaces to other programs. IAC has shown itself to be effective in automating data transfer among analysis programs.

The IAC system architecture is modular in design:

- The executive module contains an input command processor, an extensive data-management system, and a driver code to execute the application modules.
- Technical modules provide stand-alone computational capability as well as support for various solution paths or coupled analyses.
- Interface modules provide for the required data flow between IAC and other modules.
- User modules can be arbitrary executable programs of job-control-language (JCL) procedures with no predefined relationship to the IAC system.
- Special-purpose modules are included; for example, MIMIC (Model Integration via Mesh Interpolation Coefficients), which transforms field values from one model to another; LINK, which simplifies the incorporation of user-specific modules into IAC modules; and DATAPAC, the National Bureau of Standards statistical-analysis package.

The IAC data base contains structured files that provide a common basis for communication between modules and the executive system and can contain such unstructured files as NASTRAN checkpoint files, DISCOS plot files, object code, etc. A full data-manipulation and query system operates with the data base.

The current interface modules comprise the following five groups:

1. Structural analysis — IAC contains a NASTRAN interface for stand-alone analysis or certain structural/control/thermal combinations. IAC provides enhanced structural capabilities for normal modes and static deformation analysis via special DMAP sequences.
2. Thermal analysis — IAC supports finite-element and finite-difference techniques for steady-state or transient analysis. There are interfaces for the NASTRAN thermal analyzer, SINDA/SINFLO, and TRASYS II.
3. System dynamics — A DISCOS interface allows full use of this simulation program for either nonlinear time-domain analysis or linear frequency-domain analysis.
4. Control analysis — Interfaces for the ORACLS, SAMSAN, NBOD, and INCA programs allow a wide range of control-system analyses and synthesis techniques.
5. Graphics — The graphics package PLOT is included in IAC. PLOT generates vector displays of tabular data in the form of curves, charts, correlation tables, and the like. Either DI3000 or PLOT-10 graphics software is required for full graphics capability.

IAC is written in FORTRAN 77 and has been implemented on a DEC VAX-series computer operating under VMS. IAC can be executed by multiple concurrent users in a batch or interactive mode. The basic central-memory requirement for IAC is approximately 750K of 8-bit bytes. The IAC with controls-analysis modules (GSC-12992) includes interfaces and source codes for the control programs (ORACLS, SAMSAN, NBOD, and DISCOS) and full documentation for these programs. The basic IAC (GSC-12994) includes only the interfaces for the control programs. Level 1.5 of IAC was developed in 1985.

This program was written by Harold P. Frisch and Joan A. Sanborn of **Goddard Space Flight Center** *and Robert G. Vos, David L. Beste, and Joseph Greg of Boeing Aerospace Corp.*

GSC-12992 and GSC-12994 /TN

FOR ADDITIONAL INFORMATION *CONTACT:*

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112 Barrow Hall
University of Georgia
Athens, GA 30602
(404) 542-3265

NASA Tech Brief
National Aeronautics and Space Administration

Computer Software

Expert System for Automated Design Synthesis

Engineers are assisted in searching for optimum solutions.

The expert-system computer program called EXADS was developed to aid users of the Automated Design Synthesis (ADS) general-purpose optimization program. Because of the general-purpose nature of ADS, it is difficult for a nonexpert to select the best choice of strategy, optimizer, and one-dimensional search options from the 100 or so combinations that are available. EXADS aids an engineer in determining the best combination based on knowledge of a specific problem and the expert knowledge stored in the knowledge base. EXADS is a customized application of the AESOP artificial-intelligence program. (The general version of AESOP is available separately from COSMIC. The ADS program is also available from COSMIC.)

The expert system consists of two main components: the knowledge base contains about 200 rules and is divided into 3 categories: (1) constrained, (2) unconstrained, and (3) constrained treated as unconstrained. The EXADS inference engine is rule based and makes decisions about a particular situation using hypotheses (potential solutions), rules, and answers to questions drawn from the rule base. EXADS is backward chaining; that is, it works from hypotheses to facts. The rule base was compiled from such sources as literature searches, ADS documentation, and surveys of engineers experienced in optimization.

EXADS will accept such answers as "yes," "no," "maybe," "likely," and "don't know" or a certainty factor ranging from 0 to 10. When any hypothesis reaches a confidence level of 90 percent or more, it is deemed the best choice and displayed to the user. If no hypothesis is confirmed, all hypotheses with confidence levels greater than 10 percent are displayed. The user can examine explanations of why the hypotheses failed to reach the 90-percent level.

EXADS is available in two interactive machine versions. The IBM PC version (LAR-13687) is written in IQ-LISP for execution under DOS 2.0 or higher with a central-memory requirement of approximately 512K of 8-bit bytes. The DEC VAX version (LAR-13688) is written in Franz-LISP for operation under VMS. This program was developed in 1986.

This program was written by James L. Rogers, Jr., of **Langley Research Center** *and Jean-Francois M. Barthelemy of Virginia Polytechnic Institute and State University. LAR-13687 /TN*

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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Six-Axis Superconducting Accelerometer

Sensitivity and short-term stability are high.

An accelerometer design combines superconductivity and magnetic levitation to achieve linear-acceleration sensitivity greater than that of conventional linear accelerometers, and short-term angular stability better than that of conventional gyroscopes. The improved accelerometer could be used to increase precision in inertial navigation and surveying, as a sensitive multiple-axis seismic sensor, as a component of a tensor gravity gradiometer, or to sense the accelerations of stabilized platforms or spacecraft.

A conventional linear accelerometer detects changes of speed along a single axis. Thus, a conventional accelerometer system for inertial navigation requires three linear accelerometers and at least two gyroscopes. The superconducting accelerometer is a single, mechanically simple device that detects all three independent components of linear acceleration and three independent components of angular acceleration simultaneously.

The new accelerometer is housed in a liquid-helium cryostat. A precise, metallic cube (the proof mass) is magnetically levitated. The cubic configuration is compact and facilitates both the magnetic levitation and the simultaneous readout of the signals that contain information on the six independent components of acceleration.

The ac modulation is applied to the levitating coils at six inductance bridges driven at six different frequencies. All six signals are detected by one superconducting quantum interference device, which serves as an amplifier. This arrangement contributes to the compactness and economy of the accelerometer.

The accelerometer operates on the principle of force-rebalance feedback. Negative-feedback force is applied to the proof mass to operate the instrument as a null displacement detector. This feature reduces the cross-coupling of signals, increases the dynamic range, and eliminates the component of noise that originates in the external oscillator.

The linear-acceleration sensitivity of the new accelerometer is better than $10^{-12} g_E Hz^{-1/2}$ (where $g_E = 9.8\ ms^{-2}$, approximately the gravitational acceleration at the surface of the Earth). In contrast, a typical conventional linear accelerometer has a sensitivity of 10^{-6} to 10^{-9} $g_E Hz^{-1/2}$. The angular-acceleration sensitivity of the new accelerometer is 10^{-9} rad $s^{-2} Hz^{-1/2}$.

The major disadvantage of the instrument is the need for the liquid-helium cryostat or supply. Liquid helium could be transferred occasionally from a supply dewar to the cryostat, or else a closed-cycle refrigerator could be used to keep the device at the low operating temperature.

This work was done by Ho Jung Paik of the University of Maryland for **Marshall Space Flight Center**. *No further documentation is available.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for the commercial use of this invention should be addressed to

Ho Jung Paik
Dept. of Physics and Astronomy
University of Maryland
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Refer to MFS-26040, /TN

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NASA Tech Brief
National Aeronautics and Space Administration
Ames Research Center, Moffett Field, California

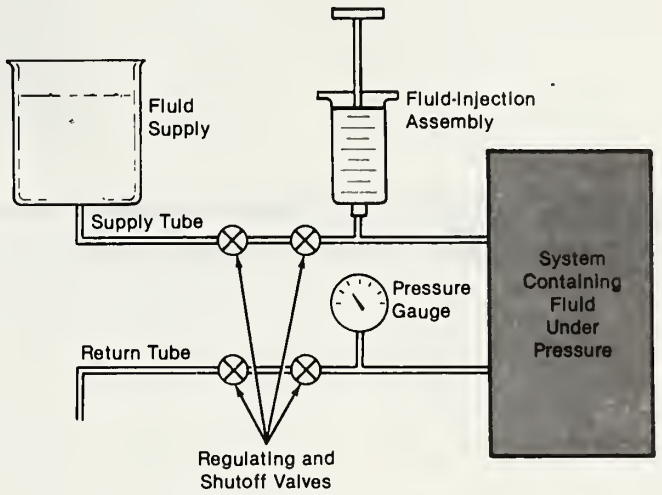
Licensing Opportunity

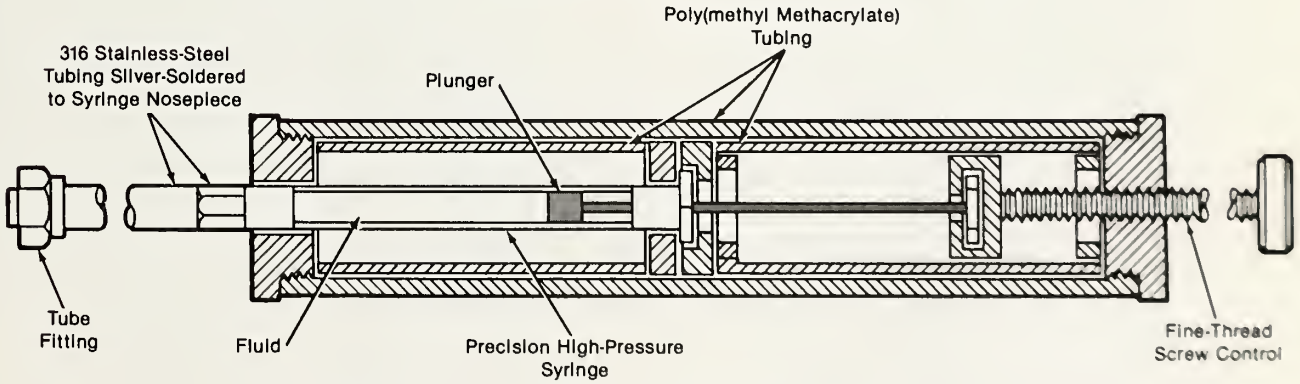
Measuring Leakage in a Pressurized-Fluid Loop

The technique can be applied to systems with inaccessible parts and connections.

Measurement of the volume of fluid added to restore the original pressure of a closed pressurized-fluid loop or system is used to determine the leak rate. In this technique, only the supply and return ports of the system need be accessible. No "bagging" of the system is required (as is often the case with helium leak testing), and system volume need not be known.

A fluid-injection assembly and regulating and shutoff valves are connected to





FLUID-INJECTION ASSEMBLY MAGNIFIED

Fluid Is Added to the system by the fluid-injection assembly to make up for leakage. The amount required to restore the pressure in the system is a measure of the leakage rate.

the supply port of the system, a calibrated pressure gauge and regulating and shutoff valves are connected to the return port, and a supply of pressurized fluid is connected to the supply tube (see figure). The fluid-injection assembly includes a precison high-pressure syringe enclosed in poly(methyl methacrylate) tubing. A tube fitting on one end connects to the system. On the opposite end, a fine-thread screw controls the plunger position.

The system is filled with fluid, bled, and pressurized to a nominal test pressure. The supply and return ports are sealed (regulating and shutoff valves closed) at the nominal pressure. After a suitable equilibration and stabilization period at constant temperature, the system pressure is adjusted to give an exact test-pressure indication on the calibrated pressure gauge. After a given test period (for example, 3 hours), during which the system may lose some pressure, the plunger of the fluid-injection assembly is adjusted until the initial test-pressure indication is restored on the calibrated pressure gauge. The measured volume of injected fluid divided by the elapsed test period yields the leakage rate.

The leakage rate may be determined at any required system pressure (for example, maximum system operating pressure), using any fluid that is virtually incompressible at the test pressure and that is compatible with the system materials. Very low leakage rates may be measured (for example, 0.04 cm^3/hour, or lower).

Test-joint leakage, gases in the test fluid, or inadequate system bleeding may contribute to an inaccurate measurement of the system leakage rate. However, these factors, which can be controlled, produce "worst-case" values. Such values can show that the specified system leakage rates are not being exceeded.

This work was done by Brian D. Clarke of Management and Technical Services Co. for **Ames Research Center**.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center
Refer to ARC-11592 /TN

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REFER TO THE NUMBER LISTED AT THE END OF THE ARTICLE

Environmental Science & Technology

33 Soil-Gas Measurements for Detection of Subsurface Organic Contamination

United States
Environmental Protection
Agency

Environmental Monitoring
Systems Laboratory
Las Vegas NV 89114

Research and Development

EPA

Project Summary

Soil-Gas Measurement for Detection of Subsurface Organic Contamination

Two techniques for soil-gas measurements were used at a site in Pittman, Nevada. Two distinct organic contaminant plumes were investigated. Twenty-three monitor wells had been drilled across the plumes to provide ground-water concentrations of benzene/chlorobenzene and chloroform. One soil-gas sampling technique (a commercial ''passive'' sampler) involved the placement of activated-charcoal-coated wires approximately 1 foot below the surface of the ground for nine days. Analysis of the samplers was made at a commercial laboratory using pyrolysis and mass spectrometer. The other technique (an ''active'' sampler) consisted of a pipe being pounded into the ground and sampled using a small hand pump and gas-tight syringes. Analysis of the samples was made using a field portable gas chromatograph.

The accuracy, precision and representativeness of the two soil gas techniques were evaluated. Closely-spaced, repetitive measurements were made in the vicinity of the monitor wells. Frequent calibrations were made on the field portable gas chromatograph to analyze the accuracy and precision of the analytical method. The data from both soil-gas techniques were compared to the data from the monitor wells to assess the representativeness of the soil-gas techniques.

The data from the commercially-marketed ''passive'' samplers exhibited a large degree of variability. It was not possible to map either ground-water plume using this method at the Pittman site. The data from the ''active'' sampler permitted the chloroform plume to be accurately mapped; however, this technique, as well as the ''passive'' technique, were unable to map the benzene/chloroform plume. Biodegradation of the benzene vapors in the vadose zone is believed to be responsible for the lack of detectable concentrations. Further studies are recommended.

Introduction

Efforts to map the extent of ground-water contamination have relied on the drilling of monitor wells. The proper location and number of wells is an issue in site investigations with cost being an important factor. Geophysical techniques have proven to be useful in locating where monitor wells should be drilled particularly when inorganic, electrically-conductive contaminants are involved. In those instances where organic contaminants are involved, particularly when concentrations are relatively low, traditional geophysical techniques are less helpful in mapping the ground-water contamination prior to the drilling of monitor wells. The sampling of vapors in the vadose zone, commonly referred to as "soil-gas" monitoring, has become increasingly attractive to those who seek additional techniques and information on the extent of organic contamination at a site.

The strengths and weaknesses of the soil-gas technique are still being researched. The number of practitioners using the technique at sites during the past few years have increased dramatically. This together with the growing number of reported instances where the technique has been used with some success would suggest that the soil-gas technique is a credible technique to consider in a site investigation along with more tested, older approaches such as those found under the general category of geophysics.

The soil-gas technique, being a relatively new technique, cannot be considered to be a standard technique with well-defined quality assurance/quality control practices being prescribed. Soil gas is typically collected with adsorbents, pipes, canisters, and bags, and the sample is generally analyzed with organic vapor analyzers, field-portable gas chromatographs, laboratory gas chromatographs and mass spectrometers. As with the placement of monitor wells, the number and placement of the less-expensive soil-gas measurement

devices is an issue also. Neither standard sampling and analytical procedures nor prescribed quality assurance precisions of the method defines the extent of ground-water contamination.

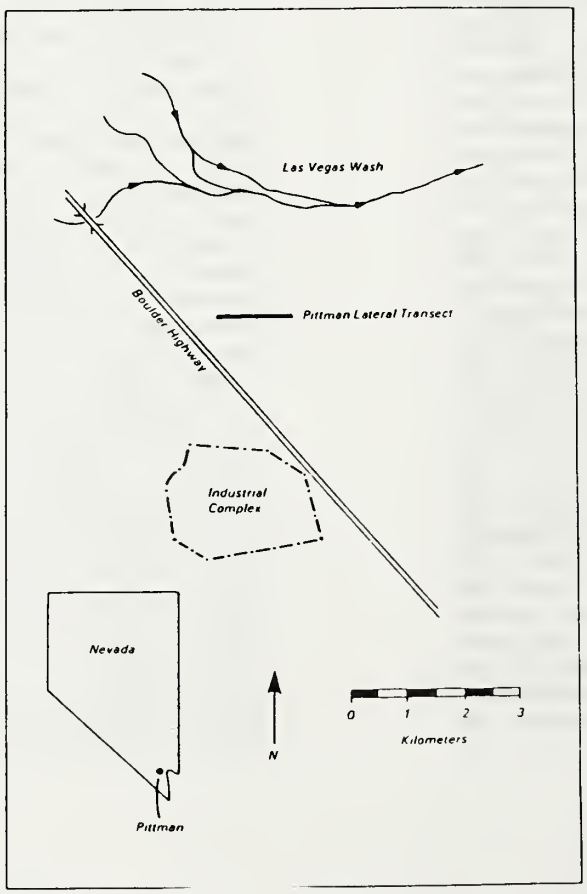
The representativeness of the method of collecting a sample is also an item of research interest. While the method appears to be capable in many investigations of being able to map contaminants in the ground water, there is some question as to whether the contaminant concentrations measured in the vadose zone can reliably measure the extent of contamination of the underlying ground water. In some cases, a soil-gas measurement may simply measure contaminants within the vadose zone or contaminants that have migrated downward from a surface spill.

The objectives of the field study described in this report were to determine the accuracy, precision and representativeness of two common soil-gas measurement techniques in mapping the contamination at a previously studied site.

Conclusions

The ability of the soil-gas probe to discern not only the center but edges of the chloroform plume in the ground water indicates that soil-gas measurements, with proper safeguards, can be of value in mapping ground-water contamination from some organic contaminants. The absence of benzene in the vadose zone indicates that caution must be exercised in the use of soil-gas measurements to map ground-water contamination. The inability of one "passive" sampling method (using activated-charcoal and pyrolysis to map organic contaminants) should not be interpreted as a failure of the general approach. After this study was completed, another "passive" method was used and the results were good. Further efforts at developing standard test procedures for the evaluation of the adsorption, desorption, and analysis phases of passive sampling are planned. Further research is also planned in evaluating the representativeness of soil-gas measurements with any method to contaminant levels in the soil, groundwater, or both.

H B Kerfoot and L J Barrows are with Lockheed Engineering and Management Services Company, Inc., Las Vegas, NV 89109
***Jeff van Ee** and **Louis Blume** are the EPA Project Officers (see below)*
The complete report, entitled "Soil-Gas Measurement for Detection of Subsurface Organic Contamination," (Order No PB 87-174 884/AS, Cost $13.95, subject to change) will be available only from
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487 4650
The EPA Project Officers can be contacted at
Environmental Monitoring Systems Laboratory
U.S. Environmental Protection Agency
P.O. Box 15027
Las Vegas, NV 89114



Location of the Pittman Site.

Manufacturing, Machinery, & Tools

34 In Process Control of Machining

35 Reference Models for Factory Automation

36 Measuring Bearing-Cage Rotation — Bearing slip would be measured optically.

37 Rapid-Solidification Processing Facility — Microstructural changes enhance properties of alloys.

38 Feedforward and Feedback Schemes Linearize Responses to Control Inputs

39 Vacuum Hold-Down System for Heat-Treating Thin Films — Vacuum is supplied alternately to different zones. (Licensing Opportunity)

40 Flexible Coupling With Centering Device — A bending cable accommodates misalignments.

41 Fast Melting and Freezing for Microgravity Experiments — Commerical tube welders are adapted to metallurgical research. (Licensing Opportunity)

42 Recursive Robot-Arm Dynamics via Filtering and Smoothing — Forward and inverse dynamics are solved using Kalman filtering and Bryson-Frazier smoothing.

43 Shaping Component Leads for Small-Scale Production — Tedious individual shaping of leads is avoided.

Testing & Instrumentation

44 Optical Monitor for Rotating Welding Turret — Built-in optics enable coaxial viewing through a torch in any orientation. (Licensing Opportunity)

Army Technology Transfer Fact Sheet

Rock Island Arsenal

In Process Control of Machining

The Manufacturing Methods and Technology Staff of the Rock Island Arsenal has demonstrated automated machine tools that produce parts in accordance with both function and form.

The program addressed two commonly encountered machining processes - milling on a vertical CNC machining center an turning on a flat bed CNC turning center.

The milling center has been in production for over a year. The center, which includes an optical sensor, measures position and area while cutting openings in the wall of a thin-walled cylinder Area must be maintained within dimensional limits so that both form and function o! the part are realized.

Prior to implementation of the computerized adaptive process, variations in area ran + or - 0.5 inch. After implementation, area variations and dimensional derivations both dropped by a factor of three. Machining has been speeded up by a factor of three and dimensional inspection, while the part is still on the machine, requires only one third of the time needed by a separate inspection on a CMM, which it will ultimately replace.

In a more recent development, two sensors and control technology have been adapted to a turning application using a Bullard CNC flat-bed lathe.

As in the milling application, the new turning operation involves inspection and control while cutting for greater accuracy. The present noncontact process can acquire 50 data sets per revolution while turning a 14 inch diameter at 400 rpm and advancing 0.025 inch. More data could be obtained per revolution by reducing the turning rate, or the turning rate can be increased by reducing the data sets acquired per revolution. The Rock Island team that led the development was headed by Raymond Kirschbaum.

For Additional Information:

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Navy Manufacturing Technology

AMRF Automated Manufacturing Research Facility

National Bureau of Standards, Gaithersburg, MD 20899

Reference Models for Factory Automation

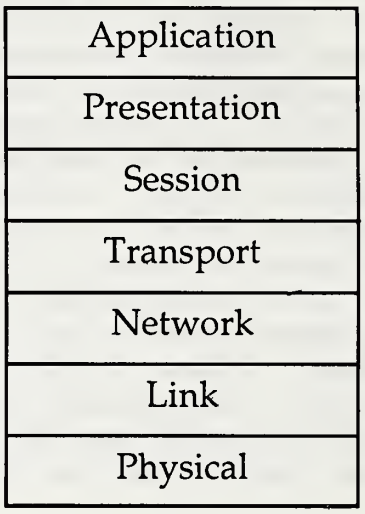
A reference model, such as the ISO seven-level model for communications, partitions a system into components for which a set of interrelating standards can be developed.

AMRF researchers, working with the standards committee ISO/TC 184/SC 5, are heavily involved in work on a reference model for systems integration in industrial automation. This reference model is expected to provide a framework for tying together much of the other AMRF work on standards involving data communication, robots, machine tools, and databases.

The core of the reference model consists of a six level hierarchical control architecture, which is based on the five layer approach used in the AMRF with the addition of a top "Enterprise" level. Commands flow in a downward direction from modules at one level to one or more modules in the next lower level. Within a given module, these commands cause four "actions" to occur: transformation, transportation, storage, and verification. These actions are applied to three "subjects": materials/resources, information, and command status. The exact definition and impact, of a particular action depends on the subject to which it is applied.

Ten "categories" and three "procedures" were also defined to aid in the identification of potential areas for standardization. The categories include: performance, safety, training, design, reliability, operability, compatibility, maintainability, environment, and documentation. The three procedures are (1) to consider all subject-action relationships for possible standards, (2) to consider all interfaces for possible standards, and (3) to consider all subject-subject relationships for possible standards.

ISO REFERENCE MODEL FOR COMMUNICATIONS



The methodology for identifying standards consists of applying these procedures and categories to each of the six levels in the reference model. This has been done, and a preliminary list of 60 standards areas has been developed. While it is clear that this list is not exhaustive, and may contain duplicates, it represents the first attempt to address this serious problem of standards for systems integration in industrial automation.

To discuss the workstations equipment further, contact:

Dr. Albert Jones
AMRF Project Manager
Building 220—Room A-127
National Bureau of Standards
Gaithersburg, MD 20899
(301) 975-3554

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

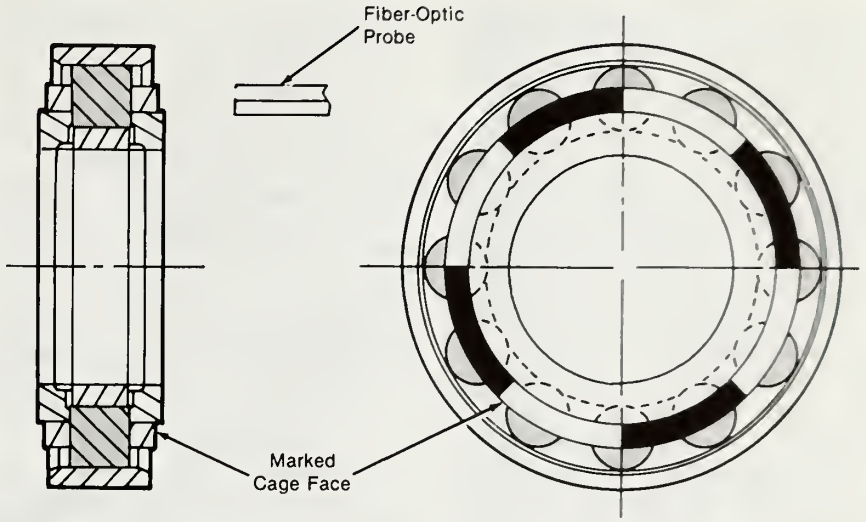
Measuring Bearing-Cage Rotation

Bearing slip would be measured optically.

A concept for measuring the rotational speed of a bearing cage promises to be simple and accurate. Based on fiber optics, the concept would require no contact between the measuring device and the bearing, and thus would not introduce wear.

The end face of a ball or roller bearing cage would be marked with light-reflecting and light-absorbing zones (see figure). An optical-fiber probe would view the zones and carry the pulses of reflected light from them to an electronic circuit. From the pulse rate, the circuit would determine the rotational speed of the cage. In combination with the measurement of shaft speed, this measurement would indicate the slip of the balls or rollers in a cage. The principle may also be used to measure the rotations of the inner and outer bearing rings.

This work was done by E. J. Roschak of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available. MFS-29182 /TN*



Alternating Bright and Dark zones on the end face of a bearing cage provide light pulses to an optical fiber. The zones would be etched on the cage.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD. 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THE ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

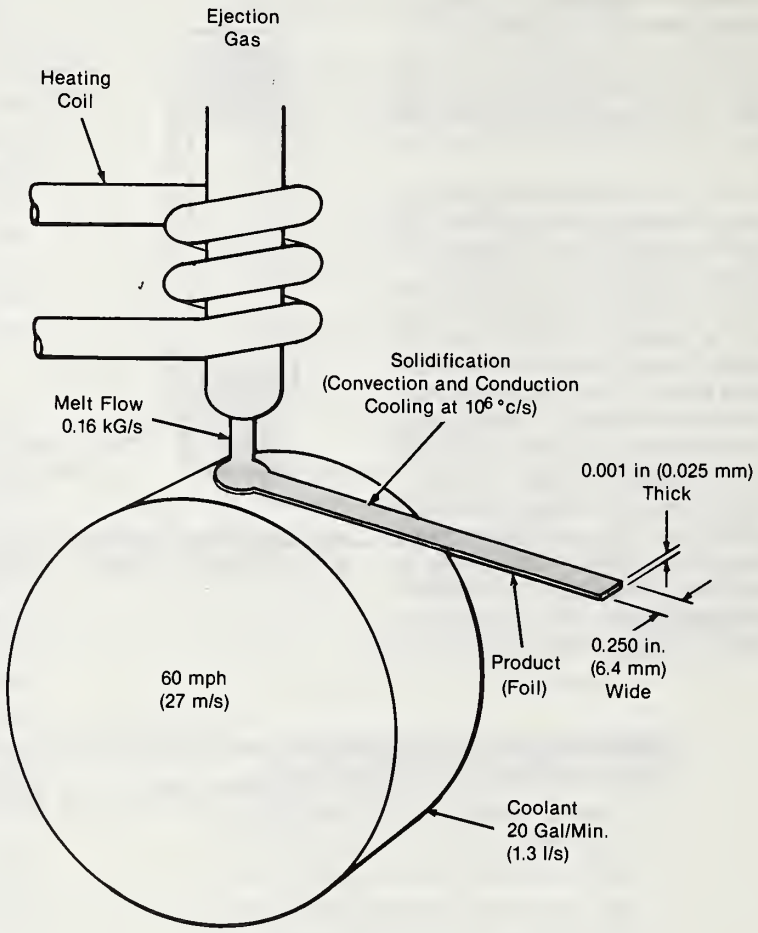
Rapid-Solidification Processing Facility

Microstructural changes enhance properties of alloys.

Rapid-solidification processing in various forms has been of interest for a number of years. A world-class facility that uses the melt-spinning rapid-solidification process is now operating at Lewis Research Center. The essential components of the facility are a source of molten metal, an ejection system, a cooled rotating substrate, a turbo/cryopump vacuum system, and a high-speed data-acquisition system. Currently, the choice of alloys for melting is limited only by the capabilities of dense alumina crucibles.

A major feature of the process is the rapid quenching of alloys or intermetallic compounds from the liquid to the solid state at cooling rates of the order of 10^6 °C/s (see figure). Such rapid solidification may have a radical impact on the physical and metallurgical natures of materials. Grain sizes are greatly reduced, the segregation of alloying elements or impurities can be minimized, and homogeneity can be greatly improved. These microstructural changes can result in physical and mechanical properties much different from those normally found in alloys quenched at more conventional rates. Preliminary research has resulted in copper alloys with fivefold increases in the solid-solution-alloying content of Cr and a resultant multiplication of strength by a factor of 4.

This work was done by Thomas K. Glasgow, Robert W. Jech, Thomas J. Moore, and Norman W. Orth of **Lewis Research Center**. *No further documentation is available. LEW-14510 /TN*


Ejection Gas
Heating Coil
Solidification (Convection and Conduction Cooling at 10^6 °c/s)
Melt Flow 0.16 kG/s
0.001 in (0.025 mm) Thick
Product (Foil)
0.250 in. (6.4 mm) Wide
60 mph (27 m/s)
Coolant 20 Gal/Min. (1.3 l/s)

A **Jet of Molten Metal** is solidified rapidly when it strikes a liquid-cooled rotating drum.

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Feedforward and feedback schemes linearize responses to control inputs.

A method for the control of a robot arm is based on computed nonlinear feedback and state transformations to linearize the system and decouple the robot end-effector motions along each of the cartesian axes in the workspace. The nonlinear feedback is augmented with an optimal scheme for the correction of errors in the workspace.

The mathematical model of the robot arm is stated in homogeneous coordinates together with the Denavit-Hartenberg four-parameter representation of robot-arm kinematics. Using the Lagrangian formulation of mechanics, the dynamic behavior of the robot arm is expressed in matrix/vector form and manipulated to obtain expressions of the types previously found useful in nonlinear-control theory.

The resulting dynamic-control mathematical model satisfies the necessary and sufficient conditions for external (or exact) linearization and simultaneous output decoupling. By using nonlinear feedback and a diffeomorphic transformation, the nonlinear system of dynamical equations is converted into a Brunovsky canonical form and simultaneously output-decoupled.

The linearization accomplished here by nonlinear feedback is an "external linearization" as opposed to the conventional "internal linearization" (Taylor-series expansion). That is, the nonlinear character of the original system is not changed here by any approximation. Therefore, system linearization by nonlinear feedback can be called "exact linearization" in a control sense.

The linearized system is unstable. To stabilize it, a linear feedback loop is added. As long as the feedback matrix is constant and block-diagonal, the system will remain an output-decoupled linear system.

A major new feature of the control method is that the optimal error-correction loop directly operates on the task level and not on the joint-servocontrol level. The task-level errors are then decomposed by the nonlinear-gain matrix into joint-force or joint-torque-drive commands.

The new control method performed well in computer simulations. The augmentation of nonlinear feedback with an optimal error-correcting control provides robust performance and assures acceptable tracking errors even when the dynamical parameters of the mathematical model of the robot arm are in error by as much as 30 percent.

This work was done by Antal K. Bejczy of **NASA's Jet Propulsion Laboratory**. *Tzyh J. Tarn of Washington University, and Yilong J. Chen of General Motors Corp.*
NPO-16742 /TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD. 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THE ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

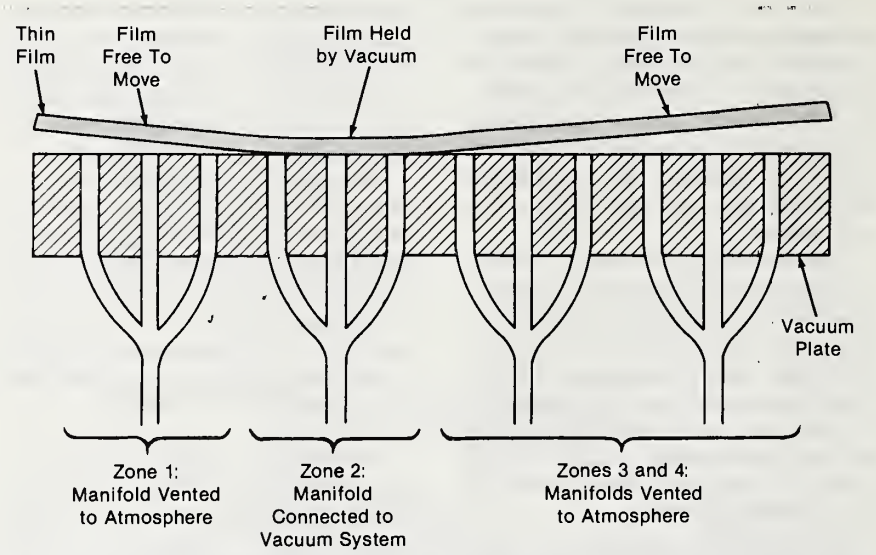
Vacuum Hold-Down System for Heat-Treating Thin Films

Vacuum is supplied alternately to different zones.

In an improved furnace concept for heat-treating thin films, the vacuum ports in the vacuum plate(s) that hold the films are connected together in zones so that the vacuum can be applied separately to each zone. This allows the material being held to shrink or expand while still being held in place. Unclamped zones expand or contract, relieving local stresses so that the entire sheet can accommodate thermally induced changes without cracking. Likely applications include the manufacture of thin semiconductor films for solar cells and of membranes for the electrolytic production of oxygen.

The vacuum is supplied in alternating pulses to each zone, with rotation to a different zone at every pulse or at an interval corresponding to several pulses, as desired (see figure). Each zone is connected to a separate vacuum manifold so that at least one zone at a time can be at ambient pressure, allowing the material overlying it to shrink or expand freely.

The zones may be arranged in many ways; for example, in concentric rings with the vacuum being applied radially, such that the clamping action "ripples" outward from or inward toward the center. Alternatively, the zones could be arranged as pie-shaped sectors, and the vacuum pulsed sequentially around a circle. The arrangement of the patterns and shapes is dependent on the material and shape of the film being held. Experimentation will find the best for each application. An experimental or universal version can be made by using a large number of small zones that can be connected together in larger groups to form various zone shapes.


Thin Film
Film Free To Move
Film Held by Vacuum
Film Free To Move
Vacuum Plate
Zone 1: Manifold Vented to Atmosphere
Zone 2: Manifold Connected to Vacuum System
Zones 3 and 4: Manifolds Vented to Atmosphere

The **Vacuum Is Applied to One Zone** at a time, so that the film is held in place in one zone but free to move in the others.

This work was done by Earl R. Collins, Jr., of Caltech for **NASA's Jet Propulsion Laboratory**.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA's Jet Propulsion Laboratory Refer to NPO-16892/TN

Jet Propulsion Laboratory
Technology Utilization Manager:
Norman L. Chalfin
Mail Stop 201-110
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-2240

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REFER TO THE NUMBER LISTED AT THE END OF THE ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Goddard Space Flight Center, Greenbelt, Maryland

Flexible Coupling With Centering Device

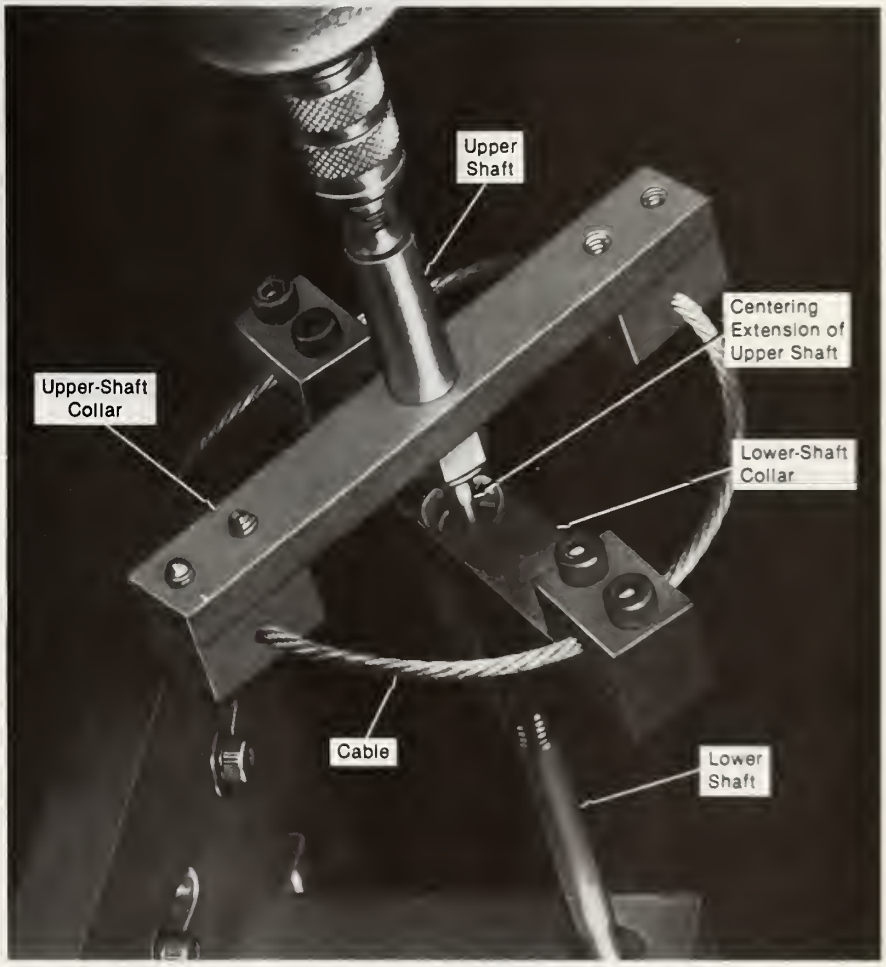
A bending cable accommodates misalignments.

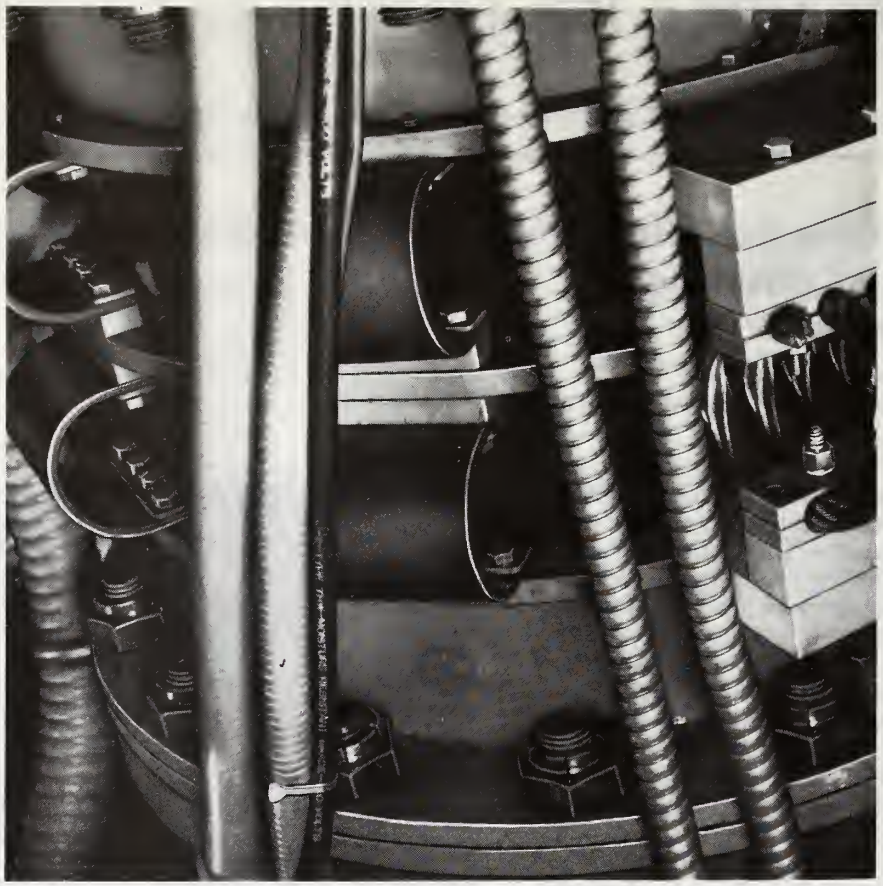
Misaligned machine shafts operating at low speeds can be coupled with a cheap, simple mechanism made in part from wire rope. The wire rope, which can be ordinary steel cable, bends to accommodate angular and lateral misalignments and dampens vibrations that accompany, or are caused by, the rotation of the shafts.

In the version shown in the upper part of the figure, the cable transmits the torque between the shafts. An extension of the upper shaft turns loosely in a hole in the collar attached to the lower shaft. This simple centering device assures that the two shafts intersect at the coupling, even when subjected to eccentric loads.

The coupling mechanism can be made in a wide range of sizes and for a wide range of torques. The version at the bottom of the figure is longer and stiffer than the one shown above and includes U-shaped leaf springs as well as cable springs.

This work was done by James Kerley of **Goddard Space Flight Center**. *No further documentation is available. GSC-12976 /TN*





The **Flexible Coupling** can be made in a variety of sizes and configurations. The one at the top functions as a universal joint. The one at the bottom is a large, relatively stiff spring coupling between wide shafts.

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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

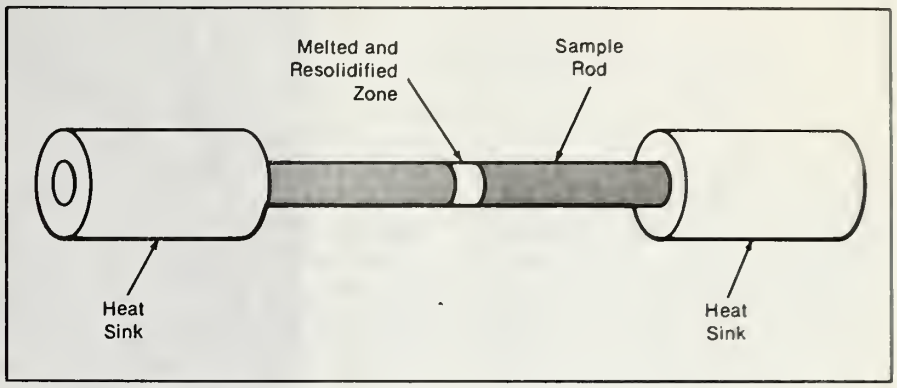
Fast Melting and Freezing for Microgravity Experiments

Commercial tube welders are adapted to metallurgical research.

A proposed furnace would melt and resolidify small metal samples during brief periods. In the furnace, a sample would be surrounded by large heat sinks and rapidly heated near its midlength by an intense source of heat. The furnace is intended for use in experiments in microgravity: the entire melting-and-freezing process would require less than the 20 s of near weightlessness that can be experienced in the parabolic climb and dive of a KC-135 airplane.

In a demonstration of feasibility, the heat source was a commercial automatic gas/tungsten-arc tube welder. In the automatic welder the arc moves around the sample at programmed speeds up to 60 r/min. The welding current is timed and programmed for up to four different current levels. The length and position of the arc are adjustable.

A variety of resolidification patterns can be provided by controlling the flow of heat to and from the samples. In the demonstration, the samples were aluminum, copper, and tungsten rods 90 mm long, with various diameters of 3 mm or more. Aluminum masses 13 mm in diameter and 25 mm long were attached to both ends of each rod to serve as heat sinks (see figure) to conduct heat axially from the heated region at the middle, thus producing directional solidification along the axis. (If the heat flow along the sample rod were reduced, the molten metal could be made to freeze from the circumference toward the middle, yielding radial solidification.)



Large Aluminum Heat Sinks are placed on the ends of a sample rod. The welding arc or other intense source of heat is applied at the middle of the exposed portion of the rod and melts a short section that resolidifies quickly as heat flows to the heat sinks.

The automatic tube welder can readily be adapted to operate on a KC-135 airplane. The 110-V, 60-Hz, 20-A power on board would be ample for the requisite welding current. The 90-lb (41-kg) welding power supply, the tube-welding head, and the operator's remote controller are easy to use. Samples can be changed readily during flight between low-gravity trajectories.

For a microgravity experiment, the furnace would be fitted with a variety of sensors. Optical and thermocouple measurements would be made of temperature, for example, and a Peltier pulser would be used to mark solidification fronts and dimensional changes. Alternative sources of heat can be used instead of the tungsten arc — a laser, an electron beam, or focused thermal radiation, for instance.

This work was done by Richard M. Poorman of **Marshall Space Flight Center.**

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center Refer to MFS-27181/TN

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Microgravity researchers measure the duration of their experiments in tens of seconds, when they can find research opportunities at all. Current sources of low gravity include drop tubes, drop towers and aircraft such as the KC-135 shown here, during a parabolic flight path.

Weightless in an aircraft, Marshall Space Flight Center scientists melt and freeze metal within 20 seconds. Using a 100-Ampere furnace, 3mm and greater diameter aluminum, stainless steel and tungsten samples are monitored as they change phase in low gravity fields.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD. 21240; (301) 621-0100 Ext. 241*

REFER TO THE NUMBER LISTED AT THE END OF THE ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration

Recursive Robot-Arm Dynamics via Filtering and Smoothing

Forward and inverse dynamics are solved using Kalman filtering and Bryson-Frazier smoothing.

The dynamics of a serial-link robot arm are solved by using recursive techniques from linear filtering and smoothing theory. The solutions of the dynamical equations give the forces, moments, and accelerations at the joints between the links, and the multilink inertia matrix and its inverse. The theoretical developments lay the foundation for the use of filtering and smoothing techniques in the design of robot controls.

The dynamical equations are written for a robot arm that has rotational joints. The innermost joint attaches the innermost link to an immobile base. The notions of spatial force, acceleration, and inertia are used to simplify the dynamical equations. A spatial force acting on a link is defined as a six-dimensional vector, the first three components of which represent a moment and the last three components of which represent a force. Similarly, a spatial acceleration is defined to be a six-dimensional vector formed by an angular acceleration and a linear acceleration. The spatial inertia of a link is a 6-by-6 matrix that expresses the mass and inertia properties of the link about its inner joint.

The equations of motion for each link can be cast as a linear difference equation that establishes a means to "propagate" the spatial force inwardly within a link from the outer to the inner joint. In addition, the continuity of the spatial force at the joints makes it possible to propagate the spatial force across a joint at the interface between two adjacent links. The recursive use of these two propagation mechanisms allows a complete link-to-link sequential propagation of the spatial force from the tip of the manipulator to its base. The difference equation generates the joint moments as an output.

The difference equation is very similar to those describing the evolution of the state of a discrete-time state-space system. The spatial force plays the role of the state. The link spatial interval, defined as the vector from the inner to the outer joint of a link, plays the role of the time interval between discrete time samples. However, it should be stressed that the equation for the spatial forces is a difference equation in space and not in time. There is no time discretization involved, and a fully continuous time evolution is retained.

Similarly, using the joint accelerations as inputs, a complementary difference equation produces a set of spatial accelerations. The spatial accelerations play the role of the costates (or adjoint variables) that are typical in optimal-control and estimation problems. This costate equation reflects the kinematic relationship between the spatial accelerations at the outer and inner joints of a link.

When combined, the state and costate difference equations define a two-point boundary-value problem. The boundary conditions are that the state (forces and moments) vanishes at the tip because the tip is unconstrained, and the costate (accelerations) vanishes at the base because the base is immobile.

The solution of this is based on filtering and smoothing techniques identical to the equations of Kalman filtering and Bryson-Frazier fixed-time-interval smoothing. The solutions prescribe an inward filtering recursion that starts from the tip of the manipulator and proceeds sequentially from link to link to the base, to compute a sequence of constraint forces and moments. Similarly, an outward iteration from the base to the tip is used to determine a corresponding sequence of link/joint linear and angular accelerations. The number of required computations grows linearly with the number of links.

This work was done by Guillermo Rodriguez of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Kalman Filtering, Smoothing, and Recursive Robot Arm Forward and Inverse Dynamics," NPO-17040 /TN*

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

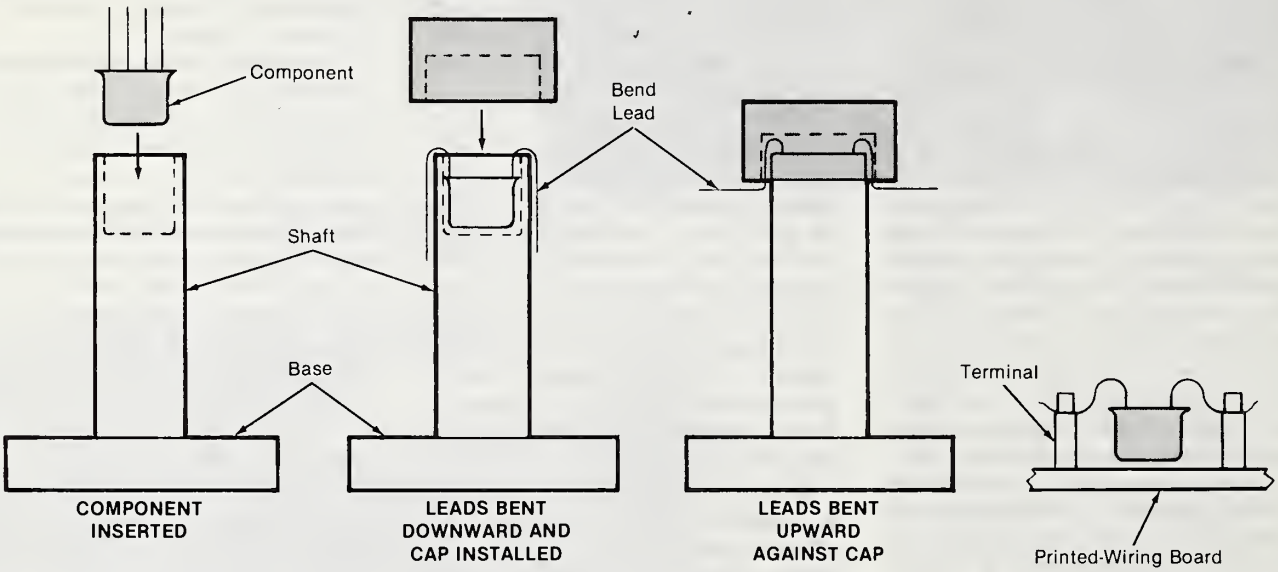
Shaping Component Leads for Small-Scale Production

Tedious individual shaping of leads is avoided.

A simple tool makes it easy to bend the leads of electronic components quickly and uniformly for assembly on a circuit board. The tool is useful in the small-scale production of electronic circuits; it saves labor but avoids the cost of complicated machinery. The tool can be made in a range of sizes to accommodate components in a variety of dimensions.

The tool includes a shaft, hollow at one end, mounted on a baseplate (see figure). The component is inserted in the tool cavity with its leads upward. The assembler bends the leads over the rim of the shaft, creating the first of two bends on each lead. A cap is then placed over the shaft, creating a base for a second bend in each lead so that they can be bonded to terminals with minimal stress.

This work was done by Lawrence Jan of Loral Electro Optical Systems, Inc. for **NASA's Jet Propulsion Laboratory**. *NPO-16863 /TN*



Lead-Shaping Proceeds Straightforwardly after insertion of an inverted component into the hollow of the tool. The assembler bends the leads downward over the edge of the tool shaft, then places a cap over the shaft. The assembler then bends the leads upward against the cap, giving them a form that can readily be mounted on a printed-wiring board.

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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Optical Monitor for Rotating Welding Turret

Built-in optics enable coaxial viewing through a torch in any orientation.

A set of internal mirrors in a welding-torch turret allows a weld seam to be monitored regardless of the angle between the turret and the torch. The turret can thus be rotated as necessary to reach various positions on the workpiece.

Mirrors are placed at the elbow between the supporting tube and the turret and within the turret, each at 45° to its respective optical axis (see Figure 1). A third mirror in the turret has a central hole, through which the welding electrode passes.

The optical system is simple and compact. It can be placed in a commercially available 90° welding torch. An additional mirror/elbow can be added to rotate the view to the desired orientation with respect to the portion of the view blocked by the

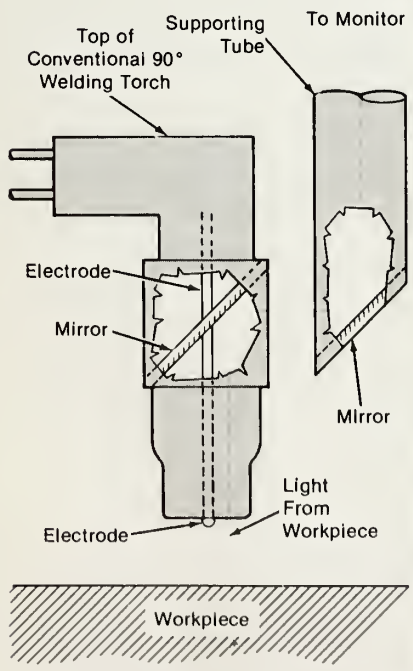

Figure 1. The **Workpiece Is Viewed** along the welding-torch axis with the help of a periscopelike arrangement of mirrors.

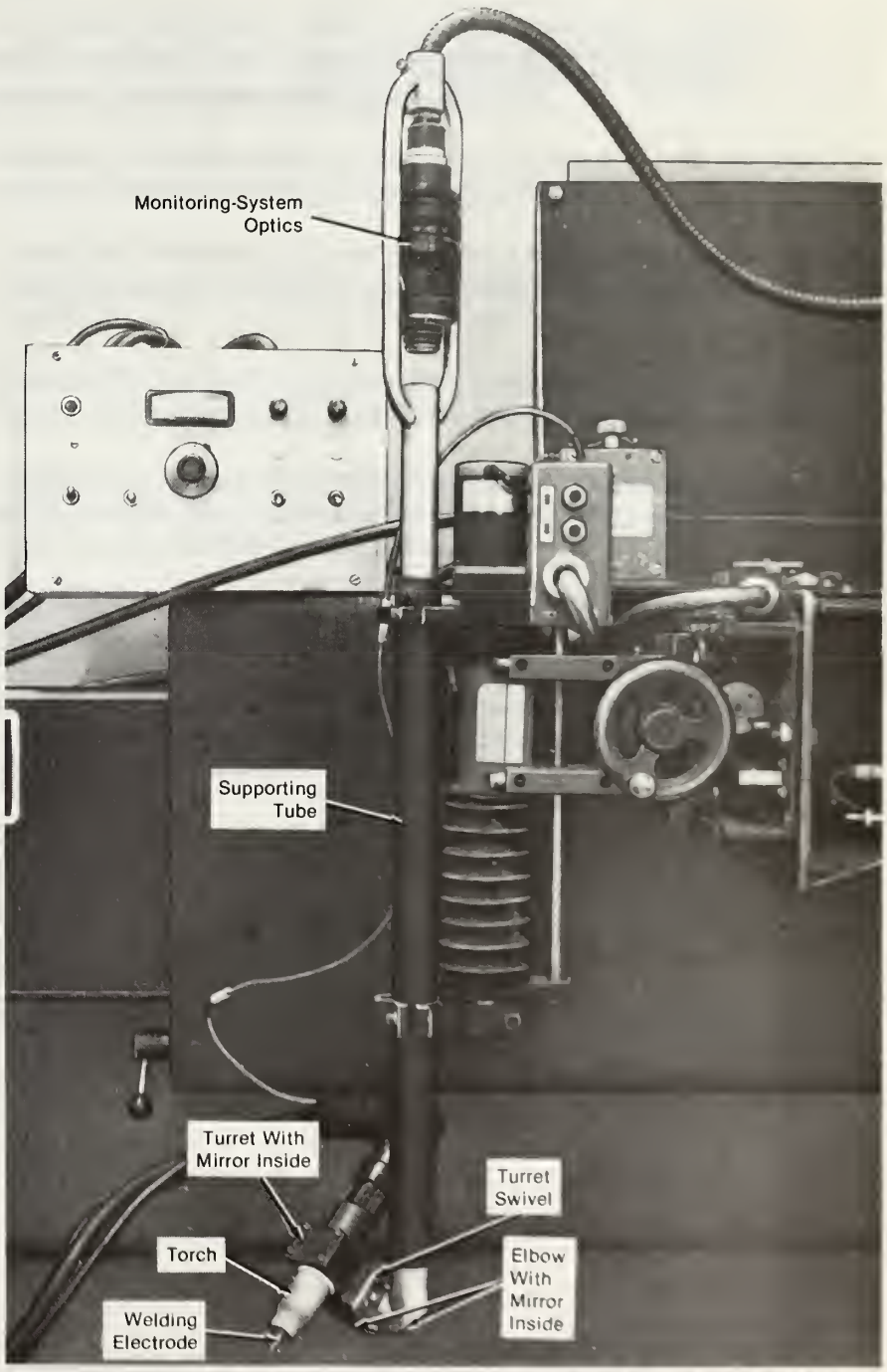

Figure 2. **Tilted at Any Angle**, an arc-welding torch still gives a clear view, through a pair of mirrors, of a weld in progress. The turret can be swiveled while the support tube remains fixed.

electrode, as in the apparatus shown in Figure 2.

This work was done by Stephen G. Babcock, Gerald E. Dyer, and Stephen S. Gordon of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center Refer to MFS-29177 /TN

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REFER TO THE NUMBER LISTED AT THE END OF THE ARTICLE

Materials

45 Characterization of Hybridized Conductive Composites

46 Lead Embrittlement of Steels

47 Polyvinyl Chloride (PVC) Wraps Reduce the Cost of Maintaining Timber Piling

48 Polyimides From BTDA, m-PDA, and HDA — Aliphatic segments in polyimide backbones help achieve low molding temperatures and resistance to solvents. (Licensing Opportunity)

49 Advanced Thermal-Barrier Bond Coatings for Alloys — New bond coatings increase service lives. (Licensing Opportunity)

50 Polyimides Containing Carbonyl and Ether Connecting Groups — Semicrystallinity gives rise to tough, solvent-resistant polymers. (Licensing Opportunity)

51 Carbide/Fluoride/Silver Self-Lubricating Composite — Bearing coatings survive at operating temperatures up to 870°C. (Licensing Opportunity)

52 Acetylene-Terminated Polyimide Siloxanes — Siloxane-containing addition poylimides yield toughened high-temperature adhesives and matrix resins. (Licensing Opportunity)

53 Thermal-Barrier Coatings Containing Ytterbia — Resistance to thermal cycling is increased. (Licensing Opportunity)

54 Aluminum Alloys for High Temperatures — New Al/Li alloys processed by rapid solidification show greatly improved strength-to-density ratios. (Licensing Opportunity)

U.S. Air Force
Technology Note

Characterization of Hybridized Conductive Composites

Considerable effort to replace primary and secondary airframe structures with advanced composite materials has resulted in significant weight savings and improved aircraft performance. However, non-structural, electromagnetic interference (EMI) critical aircraft components have not been targeted frequently as composite replacement items. Aluminum avionics enclosures and connectors often require costly secondary machining steps and frequent corrosion maintenance actions. Injection moldable thermoplastics containing conductive reinforcements have the potential to provide adequate EMI shielding, better corrosion resistance, and considerable cost and weight savings.

Work was carried out to exploit a hybridized reinforcement approach to enhance the EMI attenuation characteristics of composites. Thermoplastics filled with nickel plated graphite fibers in tandem with another fiber or flake material were studied. The electrical, mechanical, physical, electrochemical and thermal properties of these materials were evaluated.

The thermoplastics studied include polyphenylene sulfide (PPS), polyether etherketone (PEEK) and liquid crystal polymers (LCP's). The reinforcements included various combinations and concentrations of graphite (Gr) fibers, stainless steel (SS) fibers, nickel flakes (NiFlk) and nickel plated graphite (NiGr) fibers. Tensile, flexural, and drop weight impact tests were performed. Fracture morphology of tensile specimens was investigated using scanning electron microscopy (SEM). The distribution of fibers and flakes was observed using photomicroscopy. Electromagnetic interference (EMI) shielding effectiveness was determined in the range of 15 MHz to 1 GHz. Water absorption, density and electrical resistivity properties were also determined. Differential scanning calorimetry (DSC) was used to determine thermal properties. Four PPS composites provided at least 80 db of shielding at 80, 100, 150, 200 and 300 MHz respectively. The lowest electrical resistivity value measured was 0.60 ohm-cm for PPS/305NIGr/10%SS. Optical microscopy revealed that PEEK Composites with similar loadings to that of PPS composites had lower void contents. Reinforced PEEK performed better mechanically than PPS composites.

The primary objective of this investigation was to develop conductive composites with enhanced electrical properties as compared to conventional single reinforcement composites (i.e., PPS/40%NiGr). By utilizing a hybridized reinforcement approach, several materials provided these properties. These advanced conductive composites offer significant weight savings, lower processing costs, improved corrosion resistance, reduced maintenance costs and better reliability compared to existing aluminum avionics composites. In conclusion, this characterization study provides a foundation for the selection of non-metallic materials to replace metals in non-structural, EMI critical aircraft applications.

FOR ADDITIONAL INFORMATION: A copy of the report is available from NTIS, Springfield, VA 22161; (703) 487-4600.

NTIS order number: AD-A179689/5/NAA

Army Technology Transfer Fact Sheet

Army Armament Research Development and Engineering Center

Lead Embrittlement of Steels

A study has been made of the cyclic fatigue fracture behavior of single-edge notched specimens of 4340 type high strength (yield stress 160 Ksi) and alloy steel of low strength (yield stress 100 Ksi) with and without a fatigue precrack tested in liquid lead and argon at 700 F. The high strength steel specimens were severely embrittled by liquid lead with stress intensity at fracture some two orders of magnitude lower in liquid lead than in the argon environment. The embrittlement susceptibility was the same for both the notched specimens and for the specimens that had a fatigue precrack at the root of the notch. On the other hand, identical as-notched specimens of low strength steel were immune to lead embrittlement. However, when these specimens were fatigue precracked, they were severely embrittled by liquid lead. This variation is susceptibility to embrittlement is discussed in terms of the prevalent reduction in cohesion mechanism of liquid metal embrittlement. The implications of these results in determining the embrittlement susceptibility or elimination are also discussed.

Specimen	Environment	Stress	Time or Cycles to Failure	Fracture Mode
Smooth	Argon	125 ksi[a]	4 hr	No failure
Smooth	Lead	100 ksi[a]	10 min	Brittle
Precracked	Argon	135 ksi $\sqrt{in.}$[a]	3–4 hr	Ductile
Notched	Argon	135 ksi $\sqrt{in.}$[a]	No failure	–
Notched	Lead	35 ksi $\sqrt{in.}$[a]	–	Brittle
Precracked	Argon	135 ksi $\sqrt{in.}$[b]	2×10^5	Ductile
Precracked	Lead	15 ksi $\sqrt{in.}$[b]	2×10^3	Brittle
Precracked	Lead	7 ksi $\sqrt{in.}$[b]	2×10^3	Brittle

(a) Static load.
(b) Fatigue tests.

For Additional Information:

A technical report describing this research is available from the National Technical Information Service (NTIS), Springfield, VA 22161; (703) 487-4650.

Title: *Embrittlement of a High and a Low Strength Steel in Liquid Lead Environment*

NTIS order number: AD-A169 443/9/NAC
NTIS price code: A03

NAVY
Domestic Technology Transfer Fact Sheet

Polyvinyl Chloride (PVC) Wraps Reduce the Cost of Maintaining Timber Piling

INTRODUCTION

In the future, timber piling may be delivered gift-wrapped and installed with the wraps still on! In the meantime, the best thing you can do for your old, faithful timber piling, and perhaps for your waterfront maintenance budget as well, is to gift wrap those piling yourself! Thirty years of testing and use has demonstrated that flexible polyvinyl chloride (PVC) wraps effectively stop marine borer damage to timber piling. These wraps not only kill those borers already residing in the wood, but also prevent the entry of new borer recruits.

It costs the Navy about $25 million every year to combat the activities of marine borers. Loss of timber piling bearing capacity due to marine borers is the major cause of Navy wood pier failure. Fender piling also frequently fail because of borers. Treated timber piling in tropical areas have been rendered useless within five years of installation because of the ravages of these marine pests.

Marine borer damage can now be greatly reduced, if not eliminated, by the timely use of PVC wraps. In addition, selecting the proper timber piling preservative treatment for a given area can also reduce the annual cost of piling maintenance. To illustrate the cost savings of PVC wrap usage and to aid in selecting the proper preservative treatment, this TDS presents estimates of the annual costs of timber bearing and fender piling according to: (1) preservative treatment selected, (2) maintenance procedure selected, and (3) geographical region.

PRESERVATIVE TREATMENT AND MAINTENANCE PROCEDURES

The Navy relies heavily on pressure-treated timber piling for new construction in the marine environment, especially for fendering systems and for special structures such as degaussing piers. New piling can be purchased pressure treated with arsenical salts, creosote, or both (dual treatment). In addition, many old creosoted-timber piers are still serviceable. There are currently four methods of dealing with marine borer damage to these timber piling: (1) pile repair, (2) pile replacement, (3) installation of a concrete barrier, or (4) installation of a plastic (PVC) barrier. These piling maintenance options are described in MO-104 (Ref 1) but too often they are considered only after extensive damage has occurred and the least expensive option (PVC wraps) can no longer be used.

SPECIFIC RECOMMENDATIONS

1. A marine timber piling inspection plan, including specific procedures and frequency, should be developed for each facility.

2. Marine timber piling maintenance programs should include specific plans to further protect each preservative-treated piling from borer damage; PVC wrapping is most often the least expensive option available.

3. Marine bearing piling in tropical and subtropical areas should be creosoted or arsenical-treated and then protected by PVC

wraps before damage exceeds a 5% loss of cross-sectional area.

4. Marine bearing piling in temperate and polar areas should be creosoted and then protected by PVC wraps before damage exceeds a 5% loss of cross-sectional area.

5. Fender piling not exposed to high breakage rates (less than 10% per year) in tropical and subtropical areas should be arsenical-treated and then protected by PVC wraps before damage exceeds a 30% loss of cross-sectional area.

6. For fender piling not exposed to high breakage rates in cooler waters, one of the following is recommended:

(a) Arsenical-treated piling maintained either by replacement or protection with PVC wraps before a 30% loss occurs.

(b) Creosoted piling protected with PVC wrapping before a 30% loss occurs.

7. Fender pile replacement is recommended in areas with high breakage rates (10% per year or greater).

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NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Licensing Opportunity

Polyimides From BTDA, m-PDA, and HDA

Aliphatic segments in polyimide backbones help achieve low molding temperatures and resistance to solvents.

To develop a solvent- and impact-resistant thermoplastic for use in composites for aerospace applications, linear, flexible, aliphatic segments have been introduced into the backbones of rigid, aromatic, heterocyclic polymers. Polyimides prepared from pyromellitic dianhydride (PMDA) or 3,3′,4,4′-benzophenonetetracarboxylic dianhydride (BTDA) with aromatic diamines are commercially available. Less known are polyimides prepared from PMDA or BTDA with aliphatic diamines. It was found that high-molecular-weight polyimides from PMDA or BTDA with aliphatic diamines can be prepared by condensation in cresol at 180 °C. Further, high-molecular-weight copolymers containing both aromatic and aliphatic diamines can be similarly prepared.

Preferred reaction times range from 2 to 24 hours and depend on the purities of the monomers and on the monomer concentrations. Reaction temperatures above 200 °C can produce insolubles in the solution. Aliphatic diamines with PMDA produce crystalline polymers and with BTDA produce amorphous polymers. The preferred condensation technique for copolymers containing both aliphatic and aromat-diamines involves the precondensation of the aliphatic diamine with the dianhydride at 180 °C, followed by the addition of the aromatic diamine to produce the high-molecular-weight polyimide.

Moldings of the aliphatic/aromatic polyimides tested for solvent resistance showed that the crystalline polyimides from PMDA with such diamines as 1,6-hexanediamine (HDA) and 1,8-octanediamine had excellent resistance to chloroform, which dissolves many thermoplastic resins. The polyimides from BTDA with aliphatic diamines showed poor resistance to chloroform. However, when 50 mole percent or greater quantity of m-phenylenediamine (m-PDA) was substituted for a corresponding quantity of the aliphatic diamine, the resulting copolymers had excellent resistance to chloroform. The polyimides from PMDA with 1,8-octanediamine and from BTDA with 50/50 weight percents of m-PDA and 1,8-octanediamine showed no evidence of cracking or crazing under stress after exposure to acetone, chloroform, or tricresylphosphate for 500 hours.

The polymer from BTDA with equal weight percents of m-PDA and 1,8-octanediamine exhibited the following neat resin properties of tensile strength, tensile modulus, and elongation at yield: at 25 °C, 114 MPa (16,500 psi), 3,340 MPa (485,000 psi), and 5.6 percent, respectively, and at 82 °C, 89.6 MPa (13,000 psi), 2,550 MPa (370,000 psi), and 4.0 percent, respectively.

The inclusion of aliphatic moieties into the backbones of polyimide polymers lowers their glass-transition temperatures and, consequently, the temperatures required to mold them. The molding temperatures of less than 316 °C that were achieved typically lead to good fusion of such polyimides. Thus, low molding temperatures in combination with good solvent resistance make these polymers potential candidates for use in aerospace applications, particularly as matrices for fibrous composites for structural applications.

This work was done by Chadwick B. Delano and Charles J. Kiskiras of Acurex Corp. for **Langley Research Center**. *Further information may be found in NASA CR-172568 [N85-31239/NSP], [A05] "Development of an Impact- and Solvent-Resistant Thermoplastic Composite Matrix — Phase III."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center
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REFER TO THE NUMBER LISTED AT THE END OF THE ARTICLE

0048

NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

Licensing Opportunity

Advanced Thermal-Barrier Bond Coatings for Alloys

New bond coatings increase service lives.

Over the years, a variety of coatings have been developed to protect substrate metals. Because of their low thermal conductivities, ceramic coatings are used as thermal barriers in the hot sections of turbines in which hostile environments attack the standard nickel- and cobalt-base alloys.

New and improved bond coatings have been developed at Lewis Research Center for use in thermal-barrier systems on Ni-, Co-, and Fe-base alloy substrates. The use of these new bond coatings, containing ytterbium instead of yttrium, has significantly increased the lives of the resultant thermal-barrier systems.

It has been demonstrated that the (Ni/35Cr/6Al/1.1Yb)/(ZrO_2/6.1Y_2O_3) system is at least 40 percent better than the best (Ni/35Cr/6Al/0.95Y)/(ZrO_2/6.1Y_2O_3) system previously reported in the literature. CoCrAlYb and FeCrAlYb bond coatings are significantly better than the CoCrAlY bond coatings. The best nonoptimized Co- and Fe-base coatings were Co/38Cr/10Al/0.07Yb and Fe/37Cr/5Al/0.1Yb.

Although the composition of the FeCrAlYb bond coating was not optimized with respect to Yb concentration, the longest life was attained with (FeCrAlYb)/(ZrO_2/Y_2O_3), followed by optimized (NiCrAlYb)/(ZrO_2/Y_2O_3) and nonoptimized (CoCrAlYb)/(ZrO_2/Y_2O_3). Almost 1,800 1-hour cycles were obtained with (Ni/35Cr/5Al/0.10Yb)/(ZrO_2/6.1Y_2O_3) at 2,050 °F (1,121 °C) as compared to about 1,400 1-hour cycles for (Ni/35Cr/6Al/1.1Yb)/(ZrO_2/6.1Y_2O_3), also at 2,050 °F (1,121 °C).

The bond and thermal-barrier coatings were deposited by plasma spraying in open air onto alumina-blast-cleaned substrates. The cyclic testing of all thermal-barrier systems was done up to 2,150 °F (1,177 °C) in a furnace. Ni-, Co-, and Fe-base bond coatings were evaluated on Ni-, Co-, and Fe-base alloy substrates, respectively. Potential uses include many load-bearing applications in high-temperature, hostile environments.

This work was done by Stephen Secura of **Lewis Research Center**. *Further information may be found in NASA TM-87062 [N85-31283/NSP], [A02] "Advanced Thermal Barrier System Bond Coatings for Use on Ni-, Co-, and Fe-Base Alloy Substrates."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161,

This invention has been patented by NASA (U.S. Patent No. 4,485,151). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Lewis Research Center Refer to LEW-14415./TN

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NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Licensing Opportunity

Polyimides Containing Carbonyl and Ether Connecting Groups

Semicrystallinity gives rise to tough, solvent-resistant polymers.

Several new polyimides were prepared from the reaction of aromatic dianhydrides with new diamines containing carbonyl and ether connecting groups between the aromatic rings. The diamines were prepared from the reaction of 4-aminophenol with activated aromatic difluoro compounds in the presence of potassium carbonate. Representative novel diamine monomers synthesized were the following:

- 1,3-bis(4-aminophenoxy-4′-benzoyl)benzene;
- 1,4-bis(4-aminophenoxy-4′-benzoyl)benzene;
- 4,4′-bis(4-aminophenoxy-4′-benzoyl)benzophenone;
- 4,4′-bis(4-aminophenoxy-4′-benzoyl)diphenyl ether; and
- 2,6-bis(4-aminophenoxy-4′-benzoyl)naphthalene.

Several of the new polyimides were shown to be semicrystalline as evidenced by wide-angle x-ray diffraction and by differential scanning calorimetry.

Wholly aromatic polyimides are known for their exceptional thermal, thermo-oxidative, and chemical resistances. As a class, they are generally considered to be amorphous with respect to crystalline structure. The introduction of crystallinity into a polymer has long been recognized as an effective way of increasing the elastic modulus and the resistance to solvents. In addition, if the proper degree and type of crystallinity is attained, the material can also display high toughness. Most of the new semicrystalline polyimides formed tough, solvent-resistant films with high tensile properties. One of these materials exhibited very high fracture toughness and can be thermally processed.

Glass-transition temperatures of the polyimides ranged from 192 to 247 °C, and crystalline-melt temperatures were observed between 350 and 442 °C. Some of the films formed by the solution casting of polyamide acids and the subsequent thermal conversion to polyimides were tough and flexible. Tensile strengths, tensile moduli, and elongations at break ranged from 14,500 to 23,000 psi (100 to 160 MPa), 386,000 to 630,000 psi (2.66 to 4.34 GPa); and 3.3 to 39.5 percent, respectively, at 25 °C. Mechanical properties at 177 °C and 232 °C were also good.

One of the polyimides was a solvent-resistant, semicrystalline material that could be molded at 400 °C. Its fracture toughness (G_{Ic}) was exceptionally high; namely 37.8 in.-lb/in.^{2} (6.62 kJ/m^2). Its Ti/Ti tensile shear strength at 25 °C was 6,200 psi (41 MPa) and 2,600 psi (17.9 MPa) at 232 °C. In addition, the degree of crystallinity of this polyimide could be altered by either quenching from a temperature above its crystalline-melt temperature (350 °C) or annealing at a temperature slightly below its crystalline-melt temperature. These types of polymers could have potential applications in molded products, films, adhesives, and composites.

This work was done by Paul M. Hergenrother of **Langley Research Center** *and Stephen J. Havens of PRC Kentron, Inc.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center Refer to LAR-13633 /TN

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0050

NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

Licensing Opportunity

Carbide/Fluoride/Silver Self-Lubricating Composite

Bearing coatings survive at operating temperatures up to 870°C.

PS200 is a composite self-lubricating coating for bearing applications that operates at temperatures well above the failure points of such traditional solid lubricants as molybdenum disulfide and graphite. It has shown excellent friction and wear performance in oxidizing atmospheres up to 1,600 °F (870 °C) and reducing atmospheres up to 1,400 °F (760 °C). Such performance is needed for the development of such advanced heat engines as the adiabatic diesel and the Stirling engine, which will have to operate at these elevated temperatures.

PS200 is a plasma-sprayed, ceramic-based coating with solid lubricant additives. Chromium carbide was chosen for the base material because of its excellent wear resistance and thermal stability. However, it exhibits high friction coefficients when used in sliding contacts. The friction coefficient is lowered dramatically by blending in two solid lubricants: silver metal and a barium fluoride/calcium fluoride eutectic.

Because of its low shear strength, silver provides low friction at low temperatures, and the eutectic has been shown to effectively lubricate above 900 °F (480 °C). Like chromium carbide, silver and the fluoride eutectic are thermally and chemically stable to at least 1,650 °F (900 °C). Since silver lubricates from low to moderately high temperatures, and the eutectic lubricates at high temperatures, the resulting composite lubricant does not show any sharp discontinuities in its friction and wear behavior over a wide temperature range. The coating system is designed to lubricate successfully in applications where low-temperature starts and high operating temperatures are encountered.

PS200 has a composition of 80 weight percent metal-bonded chromium carbide, 10 weight percent silver metal, and 10 weight percent barium fluoride/calcium fluoride eutectic. The surface to be coated with the composite is first sandblasted; then a thin bond coat of nickel/chromium powder is plasma-sprayed onto the roughened surface. The PS200 composite, prepared in a blended powder mixture, is plasma-sprayed onto the bond coat, and then diamond ground to the finished bearing surface.

This work was done by Harold E. Sliney of **Lewis Research Center**. *Further information may be found in:*

NASA TM-86943 [N85-20127], [A02] "The Role of Silver in Self-Lubricating Coating for Use at Extreme Temperatures,"

NASA TM-86895 [N85-14928], [A03] "Effects of Silver and Group II Fluoride Additions to Plasma Sprayed Chromium Carbide Coatings for Foil Bearings to 650 °C,"

NASA TM-87274 [N86-21682], [A02] "A New Chromium Carbide-Based Tribological Coating for Use to 900 °C with Particular Reference to the Stirling Engine," and

NASA TM-87261 [N86-20568], [A03] "Composition Optimization of Self-Lubricating Chromium Carbide-Based Composite Coatings for Use to 760 °C."

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161.

Inquires concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center Refer to LEW-14196 /TN

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NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Licensing Opportunity

Acetylene-Terminated Polyimide Siloxanes

Siloxane-containing addition polyimides yield toughened high-temperature adhesives and matrix resins.

The need in space research for polymers with enhanced high-temperature capabilities led to the development of linear systems that were impossible to process in high-molecular-weight imide form. More recently, aromatic addition polyimides have been developed as matrix and adhesive resins for applications on future aircraft and spacecraft. Addition polyimides offer distinct advantages over linear polyimides, in that the former can be processed in the form of short-chained oligomers end-capped with latent cross-linking groups. The polymerization of this type of material in place makes it useful as an adhesive. This same processing method can be used for the preparation of fiber-reinforced composites where the polymerization encapsulates the reinforcement and is set.

One particularly attractive addition-type polyimide that is commercially available has the structure shown in Figure 1. It is prepared by the reaction of an aromatic tetracarboxylic acid dianhydride with an aromatic diamine in the presence of an ethynyl-substituted aromatic monoamine to provide a fully imidized, acetylene-terminated thermosetting polyimide resin. Unfortunately, it is insoluble in all solvents except in N-methylpyrrolidone at 100 °C, which leads to the problems associated with removal of this high-boiling-point polar solvent.

Addition polyimides of this type tend to be highly crosslinked, insoluble, and extremely brittle on curing. Efforts made to toughen addition polyimide adhesives (LaRC-13, for example) by physically blending fluorosilicone and vinyl-terminated silicone rubbers were partially successful. If the siloxane group were chemically incorporated in the polyimide backbone, the effect could be far more pronounced. The resulting siloxane-containing addition oligomer would also have improved solubility by virtue of the flexible —Si—O—Si— linkage.

The process involves the reaction of a diaminosiloxane with acetylene-terminated anhydrides of varying chain lengths. Aminophenyl acetylene (APA) and an aromatic dianhydride are reacted in different molar ratios to develop ethynyl-terminated anhydrides with a range of molecular weights. The anhydride thus formed may be reacted with a diaminosiloxane to yield an acetylene-terminated oligomer, which on curing, yields the acetylene-terminated polyimide siloxane. Figure 2 shows the structure of one of the acetylene-terminated siloxane imides.

The oligomer melts in the temperature range of 125 to 160 °C and undergoes curing between 190 and 270 °C. The oligomer may be extended using different proportions of an aromatic dianhydride and APA. It may be blended further with commercially available resins, like that of Figure 1, with which it is fully compatible.

Scrim cloths can be prepared with these resins by the conventional method of repeatedly coating on glass cloth, allowing to air dry, then imidizing thermally. Scrim cloths can also be prepared by melt-impregnating glass cloth with dry resin powder using localized heating, thus obviating the need for solvents, which are difficult to

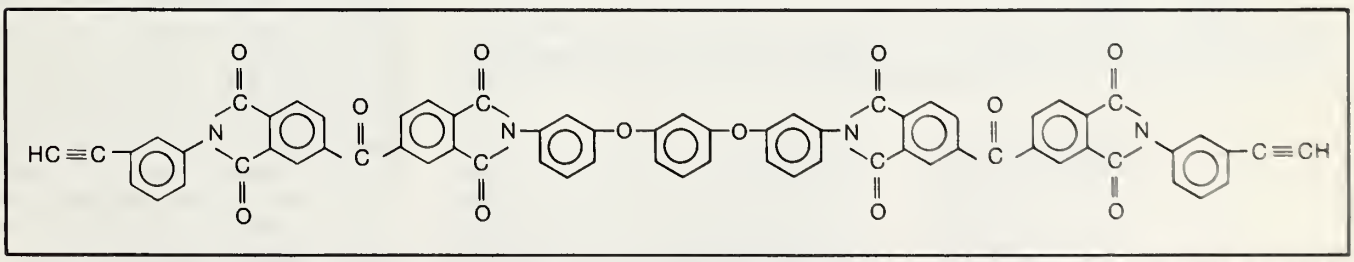

Figure 1. This **Addition Polyimide** is made by the reaction of an aromatic tetracarboxylic acid dianhydride with an aromatic diamine in the presence of an ethynyl-substituted aromatic monoamine.

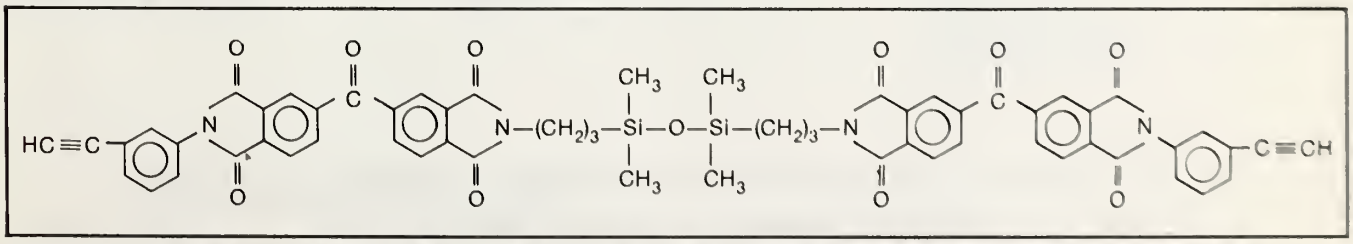

Figure 2. This **Acetylene-Terminated Siloxane Imide** can be cured by heating to yield an acetylene-terminated polyimide siloxane.

remove.

Adhesive bonds using these scrim cloths have relatively good lap-shear strengths. Composites prepared from these oligomers can be thermoformed at elevated temperatures after an initial molding in the temperature range of 175 to 200 °C due to the lowered melting temperatures. A range of service temperatures results from blending the oligomers with various acetylene-terminated resins in different proportions.

This work was done by Terry L. St. Clair of **Langley Research Center** *and Shubba Maudgal of the Institute for Computer Applications in Science and Engineering. For*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center Refer to LAR-13318./TN

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NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

Licensing Opportunity

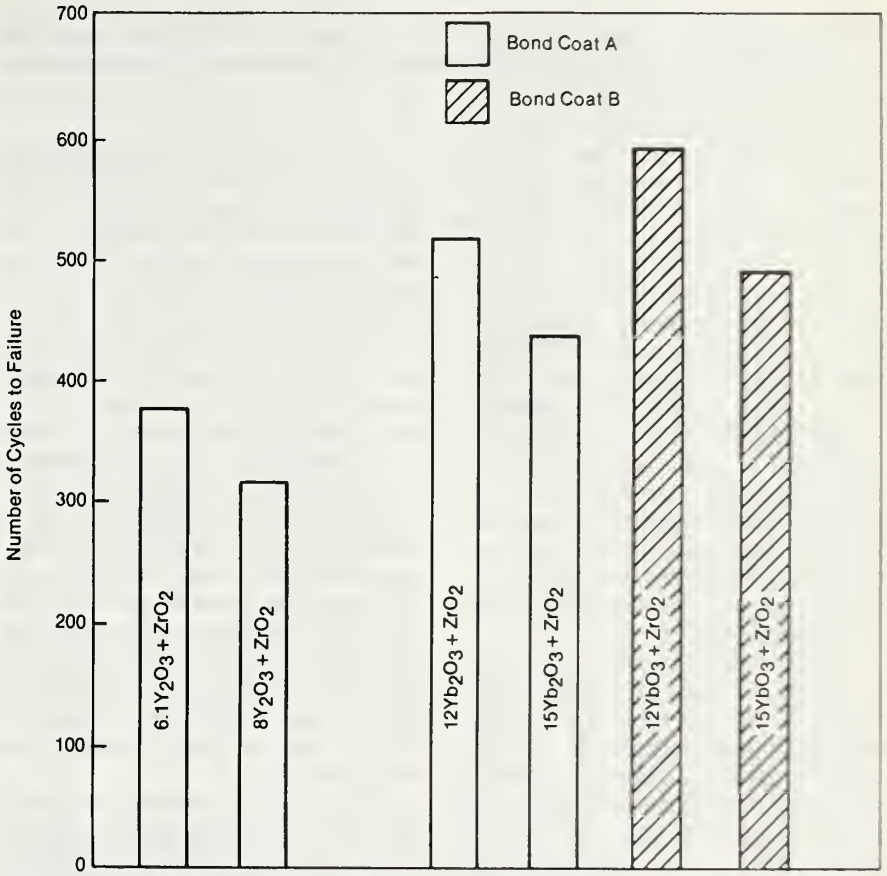
Thermal-Barrier Coatings Containing Ytterbia

Resistance to thermal cycling is increased.

High-temperature thermal-barrier coatings are used to protect substrate materials from degradation by high temperatures and by thermal cycling. A thermal-barrier coating generally consists of thin oxide layers that have been plasma- or arc-sprayed on a prepared surface. One of the most effective high-temperature thermal-barrier materials is zirconia (ZrO_2) stabilized with yttria (Y_2O_3). Yttria concentrations in the range of 6 to 8 percent have demonstrated optimum properties.

A new outer ceramic coating layer for a two-layer (bond coat plus overlay) or graded thermal-barrier coating has been developed. This new ceramic overlay is zirconia stabilized with ytterbia ($ZrO_2 + Yb_2O_3$) and is used in conjunction with NiCrAlY or NiCrAlYb bond coats. This new two-layer system has been evaluated in furnace testing at temperatures cycled between 2,025 °F (1,110 °C) and 575 °F (300 °C). Overlay coats of zirconia (ZrO_2) stabilized with 12 and 15 percent ytterbia ($12Yb_2O_3$ and $15Yb_2O_3$) when used over bond coat A (Ni + 16.5Cr + 5.92Al + 0.17Y) and bond coat B (Ni + 17.5Cr + 6.6Al + 0.22Yb) increased the numbers of thermal cycles to failure. An overlay coat $ZrO_2 + 12Yb_2O_3$ on bond coat A increased the life 60 percent over that of the base material ($ZrO_2 + 6.1Y_2O_3$ overlay on bond coat A). With bond coat B, $ZrO_2 + 12Yb_2O_3$ overcoat had a 90-percent greater life than did the base material. The figure shows the longevities of the various coatings in the cyclic tests. Additional work may result in improved bond-coat compositions.

This work was done by Stephan Stecura of **Lewis Research Center**. *No further documentation is available.*



The Longevities of Thermal-Barrier Coatings were measured in a furnace in which the temperature was repeatedly varied between 575 and 2,025 °F.

This invention has been patented by NASA (U.S. Patent No. 4,535,033). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Lewis Research Center Refer to LEW-14057/TN

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NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Licensing Opportunity

Aluminum Alloys for High Temperatures

New Al/Li alloys processed by rapid solidification show greatly improved strength-to-density ratios.

Titanium alloys and 2XXX-series aluminum alloys are currently used in aerospace structural applications requiring service in the temperature range of 250 to 500 °F (120 to 260 °C). Although titanium alloys have high strengths, they have densities higher than those of the aluminum alloys. The 2XXX aluminum alloys have low strengths with severe losses of strength at temperatures above 300 °F (150 °C). Aluminum/lithium alloys have very low densities and high strengths at ambient temperature and are thus attractive candidates for improved ratios of strength to density at high temperatures. However, previous work on Al/Li alloys processed by ingot metallurgy and rapid solidification has shown significant degradation of strength following exposures to high temperatures longer than 1 hour. Improved Al/Li alloy compositions are required to produce high strengths for long exposures to high temperatures.

Al/3Cu/2Li/1Mg/0.2Zr, Al/3Cu/2Li/1Mg/1Fe/1Ni/0.2Zr, and Al/3Cu/2Li/1Mg/1.6Cr/0.2Zr alloys processed by rapid solidification were prepared with strength-to-density ratios up to 15 percent greater than those of solution-treated and aged titanium alloys and up to 34 percent greater than those of mill-annealed titanium alloys exposed for more than 100 hours at temperatures of 75 to 300 °F (25 to 150 °C). The new alloys have strength-to-density ratios up to 56 percent greater than those of conventional high-temperature 2XXX alloys at 25 to 150 °C and up to 118 percent greater at 260 °C for exposure times in excess of 100 hours at the stated temperatures. In addition, the new alloys have strength retention (strength at high temperature divided by strength at ambient temperature) superior to that of all competitive titanium- and aluminum-based alloys used at temperatures up to 150 °C.

Powders of the new alloys are produced by inert-gas atomization at solidification rates in excess of 10^3 K/s. The powders are consolidated by cold pressing, canning, vacuum degassing, vacuum hot pressing, and hot extrusion. This rapid-solidification processing allows segregationless incorporation of the Cu, Li, and Mg, which make precipitates that provide large increments of strength after exposure up to 150 °C for long times. The processing enables the production of incoherent dispersoids, containing either Fe + Ni or Cr, of sufficiently small diameter and homogeneous distribution to increase significantly the strength at high temperatures.

These alloys are promising candidates for use in structural members that must be able to withstand temperatures of at least 150 °C for long times without losses in properties, as in such high-performance aircraft as supersonic fighters, bombers, and transports. The alloys are suitable substitutes for heavier titanium alloys and weaker aluminum alloys in these applications. They are also suitable for use in those high-performance-aircraft structures that are heated by engines and that are normally constructed from titanium alloys. The new alloys can be used in these applications with significant reductions in structural weight.

This work was done by Peter J. Meschter, Richard J. Lederich, and James E. O'Neal of McDonnell Douglas Corp. for **Langley Research Center**. *Further information may be found in NASA CR-178145 [N86-31698/NSP], [A04] "Study Effects of Powder and Flake Chemistry and Morphology on the Properties of Al-Cu-Mg-X-X-X Powder Metallurgy Advanced Aluminum Alloys — Final Report."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161,

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center Refer to LAR-13632./TN

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REFER TO THE NUMBER LISTED AT THE END OF THE ARTICLE

Medicine & Biology

55 Graphite Spark Emission

Testing & Instrumentation

56 New MR Coils Allow Clinicians to See the Anatomy of Patients and Study the Chemistry of Their Tissues

57 Portable Speech Synthesizer — A compact speech synthesizer can be a useful traveling companion to the speech-handicapped. (Licensing Opportunity)

Other items of Interest

2 Artificial Gene Aids Study of Oilseed Crops

NIH
Research & Technology

Federal
Technology
Resource

U.S. Department of Health and Human Services Public Health Service National Institutes of Health

Graphite Spark Emission

Simultaneous measurements of subnanogram amounts of several biologically important elements can be obtained by using the graphite spark emission apparatus available in the Chemistry Department of the Memphis State University, Memphis, Tennessee.

The graphite spark emission apparatus, which is supported by the College of Arts and Sciences of the Memphis State University, can be used to analyze samples in volumes of 1 nanoliter or less.

The graphite spark technology has several advantages over other currently available techniques, such as the electron probe and atomic absorption spectrometry. The major advantage is that little sample preparation is needed; the other techniques often require extensive sample preparation. For example, samples consisting of electrolytes dissolved in water can be analyzed using the graphite spark technique simply by drying a drop of solution on an electrode. Limited preparation is especially ideal for small samples, because every time the samples are handled, elemental concentrations can be increased or decreased by contamination, says Dr. James C. Williams, professor of chemistry and principal investigator for the graphite spark project.

Another advantage of the graphite spark apparatus is that it is considerably cheaper to use than other currently available techniques. With the graphite equipment researchers can analyze electrolytes that cannot be studied by other techniques and these electrolytes can be examined in smaller quantities than usually required by other techniques.

The graphite spark emission technique was one of the earliest methods developed for analyzing extremely small samples of elements, but it was followed by development of other technologies that were very successful at quickly analyzing different samples. Due to recent improvements in electronic devices the graphite spark emission technique again appears promising for analyzing smaller samples, the investigator says.

The primary utility of the graphite spark emission apparatus is to enable researchers to study the function of trace elements. Many samples of biological interest can only be obtained in minute quantities and cannot be studied using some of the other available techniques, Dr. Williams notes.

Before a sample is analyzed, a known quantity of lithium is added as an internal standard. An internal standard is needed because the spark is a transient phenomenon; sometimes it will excite a sample more than it does at other times because of the uneven distribution of the sample on the graphite rods. Because the emission intensity ratio of the internal standard to the analyte remains the same, calculations of sample concentrations can be made. Lithium is used because it is normally not

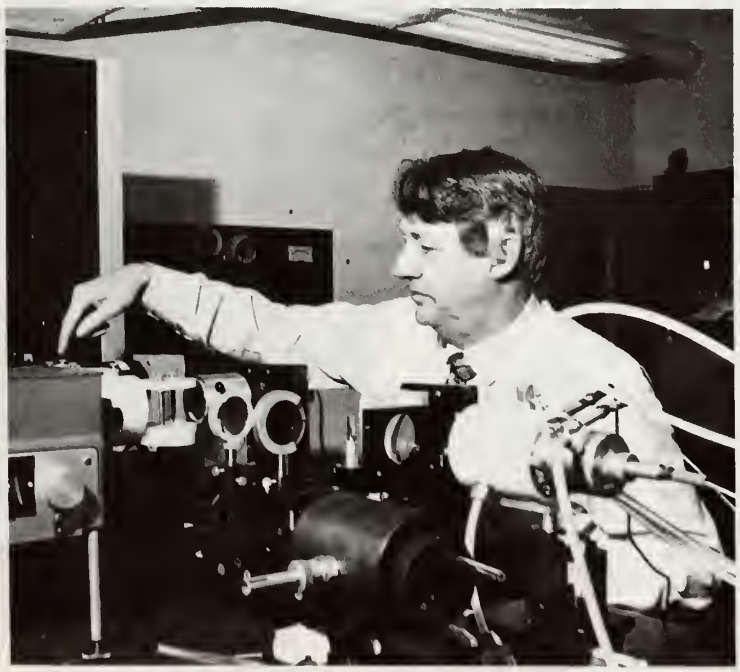

Photo courtesy of Tom Wofford, Memphis State University Photography Services

Dr. James C. Williams, professor of chemistry at the Memphis State University, Tennessee, uses the graphite spark emission apparatus to examine several subnanogram amounts of biologically important elements. Samples of 1 nanoliter or less can be studied simultaneously.

found in living species, and therefore should not appear in the samples being studied, Dr. Williams explains.

To analyze trace elements and other biologically important elements, researchers take the samples of interest that already contain the internal standard and dry them on grease-covered graphite rods. The grease makes the rods nonporous and so prevents sample loss. After the samples are dry, they are volatilized by high voltage, low inductance sparks that consume the lithium and the other elements in the sample. Dr. Williams points out that only one spark is needed to gather enough information about the concentrations of the elements present in the sample.

A photomultiplier tube detects and amplifies the small amount of light emitted from each element, such as potassium, calcium, and sodium, as well as the lithium. A computer records the information from the signals detected by the tubes, and also analyzes the data.

It only takes a few minutes to run a sample using the graphite spark technique, although the apparatus must be calibrated by running a set of standards with known concentrations before and after each set of experimental samples.

Dr. Williams is currently building a 6-channel spectrometer to expand the use of the graphite spark technique. This instrument will enable researchers to study six different samples simultaneously, instead of just one sample at a time.

—Barbara J. Proujan

For more information about the graphite spark emission apparatus, contact:
Dr. James C. Williams
Chemistry Department
Memphis State University
Memphis, Tennessee 38152
Telephone: (901) 454-2638

Magnetic Resonance Imaging Conference

A National Institutes of Health consensus development conference on magnetic resonance imaging will be held October 26 to 28, 1987, at the NIH Clinical Center in Bethesda, Maryland.

The conference is sponsored by the Clinical Center and the Office of Medical Applications at the NIH; the Division of Research Resources; the National Cancer Institute; the National Heart, Lung, and Blood Institute; the National Institute on Aging; the National Institute of Neurological and Communicative Disorders and Stroke; the Food and Drug Administration; and the National Institute of Mental Health.

Topics to be discussed include the efficacy of magnetic resonance imaging, contraindications to or risks of MRI, technological advances and limitations, clinical indications, how MRI compares with other diagnostic modalities, and directions for future research in MRI.

For more information, contact:
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Rockville, Maryland 20852
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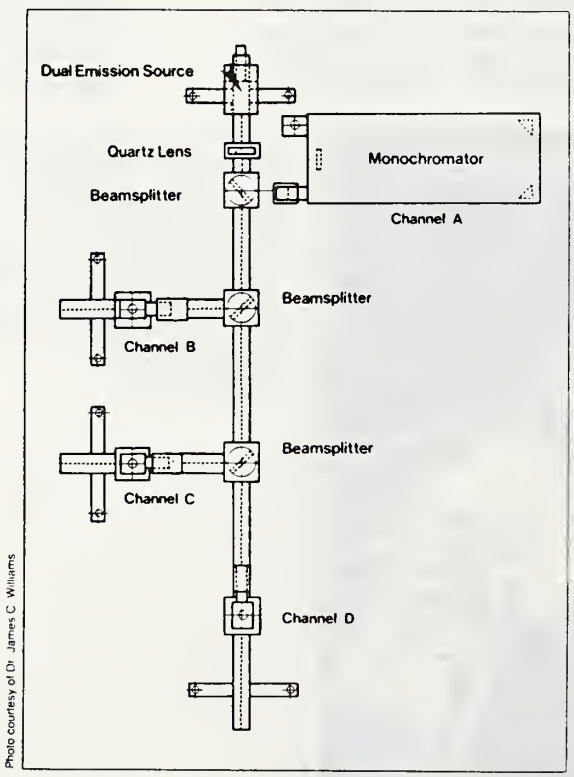

Photo courtesy of Dr. James C. Williams

The graphite spark emission technique is mainly used in studying the function of trace elements. A sample with a known amount of lithium is placed at the arrow and then volatilized by low inductive sparks. The light emitted from each respective element in the sample is detected by channel A, B, or C. A computer records the information from the channels and is used for analysis.

NIH
Research & Technology

U.S. Department of Health and Human Services Public Health Service National Institutes of Health

New MR Coils Allow Clinicians to See the Anatomy of Patients and Study the Chemistry of Their Tissues

It has been called the biggest single advance in diagnosis since the discovery of X rays, a method for imaging and, in some instances, chemically analyzing body tissues by recording the behavior of atomic nuclei in living cells.

Since the early 1980's this technique, called magnetic resonance imaging (MRI), has produced dramatic views—cross sections of the brain, spinal cord, heart, lungs, abdomen, and blood vessels—views that often cannot be seen any other way. All are done noninvasively and free of ionizing radiation.

Some of the most detailed images are now being produced at the Medical College of Wisconsin (MCW) in Milwaukee using radio antennas, called surface coils, fitted to specific parts of the body. Several have shown the anatomy with such detail and clarity that radiologists at the MCW imaged and then obtained photographs of corresponding sections from cadavers to confirm that the structures they saw were actually there.

"We had great difficulty understanding the image until we examined the anatomy of several cadaver shoulders and worked out the details," says Dr. J. Bruce Kneeland, an MCW radiologist. "What we're doing is pretty much state-of-the-art."

Dr. Kneeland is liaison between the clinicians who use the coils and the physicists who design and build them. "I can explain the problems and suggest ideas that I know are physically possible but that the physicists may not have thought about because they didn't know what the ultimate clinical application would be," he says.

Dr. James S. Hyde, a physicist and professor of radiology at MCW, comments that sometimes this equation gets turned around. The physicists occasionally design new coils with clinical capabilities that physicians had not previously considered. "This is the true nature of interdisciplinary research," says Dr. Hyde, who directs the National Biomedical Electron Spin Resonance Center where the coils are built.

Superb imaging is only one capability of these coils. Another and arguably an even more exciting one, is the chemical analysis of tissues inside the body through the use of magnetic resonance spectroscopy.

According to Dr. Thomas M. Grist, a physician and also a research associate in radiation biophysics, the technology now being developed at MCW brings to the forefront of medicine what has long been little more than a hope: that noninvasive machines might provide information other-

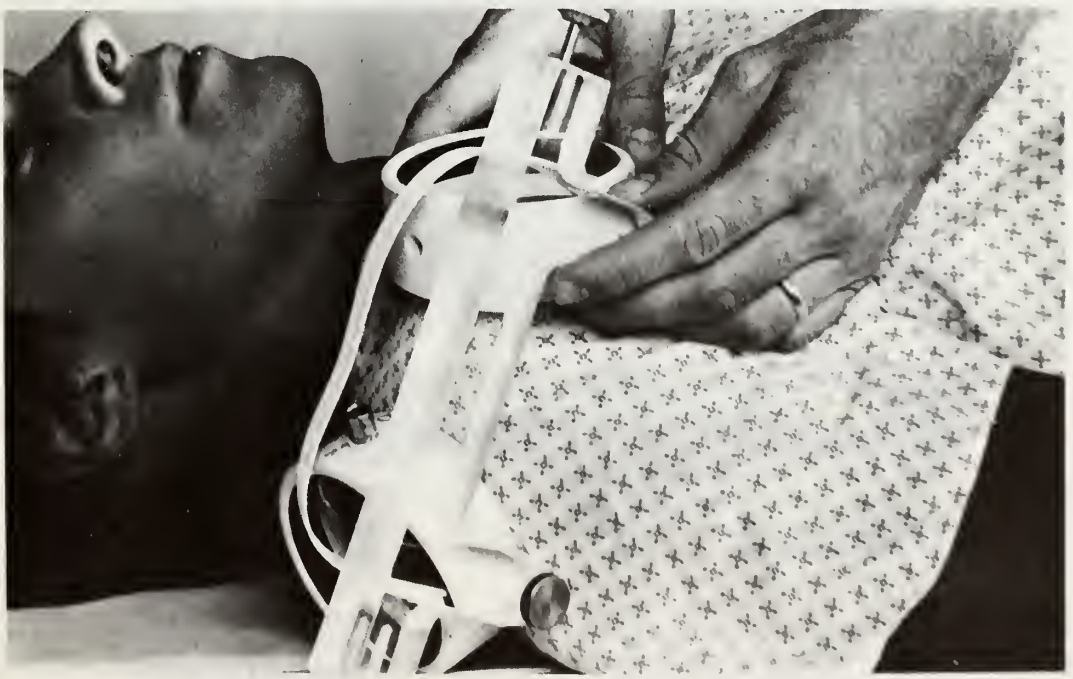

Photo courtesy of the Medical College of Wisconsin in Milwaukee

Surface coils are crafted to fit specific parts of the human body. With the shoulder coil researchers at the Medical College of Wisconsin in Milwaukee have obtained images superior to those possible with conventional magnetic resonance imaging.

wise available only through surgery and biopsy.

Unlike the scalpel or needle, the coils rely on electromagnetic waves to sample tissue, transmitting energy and receiving signals sent back by atomic nuclei in the body. From these signals are produced images as well as spectra that show the concentrations of various chemicals.

In MR imaging and spectroscopy, nuclei such as the ones in hydrogen and in phosphorus act like tiny magnets, each with a positive and negative end. When placed in a steady magnetic field, the atomic nuclei in a patient's tissues align with the field. Radiofrequency waves are then pulsed across the patient, exciting the nuclei and causing them to reorient. The nuclei then broadcast radio waves that can be picked up by the coils. During this transmission, the nuclei "relax" and align again with the magnetic field.

In magnetic resonance imaging, a computer creates an image by interpreting signals received from different parts of the body. The relaxation time of the atomic nuclei, their concentration, and their motion provide the contrast in the pictures. Cancer tissue, for example, often has an increased number of mobile protons (mostly water) that may result in an image in which the tumor appears as having a different intensity from the surrounding normal structures. The tumor may appear, for example, as a bright white circle against the gray background of normal tissue. Similarly, by tuning the receiver to the radio frequency transmitted by phosphorus or some other element, MR spectra are obtained.

The simplest loop-gap resonator is a loop of wire, the ends of which come close together to form a gap. The design has proved to be a breakthrough in ESR spectroscopy as well as in magnetic resonance imaging and spectroscopy. Structures with a number of loops and gaps have been built to serve different applications.

Extending the design of the ESR loop-gap resonator to magnetic resonance imaging and spectroscopy was carried out by Drs. Hyde, Froncisz, Kneeland, Grist, and Andrzej Jesmanowicz, a physicist and Polish emigre. These researchers constitute the coil development team at MCW.

The coils that allow both imaging and spectroscopy are among the most sophisticated and experimental of the more than 20 coils developed for clinical use at MCW. But the others, which also are based on principles applied in ESR studies, have produced striking clinical images of hard-to-examine areas—the eye socket, neck, wrist, spine, knee, ankle, and fingers.

MR coils are especially useful in imaging spinal injuries because these injuries require very specific and exact images, the kind only coils, with their concentrated focus, can provide. But other coils are routinely applied even when conventional imaging could be used.

A different MR coil has produced sharp images of the temporomandibular joint (TMJ) on which the jaw moves. The coil is particularly useful after the implant of disc prostheses in patients with severe damage to the native disc. Conventional methods cannot visualize the implant. Before the coil was available, a suspected break in the prosthesis could be confirmed only by surgery.

The MCW team is continuing to build coils. Some are being fashioned specifically for children, whose small body size requires images with especially high resolution.

The researchers are also planning strategies for using the coils already in hand. One idea is to combine several coils to image large stretches of the body, such as a string of coils that would detail the entire spine.

The primary concern in spectroscopy is just to gain a better understanding of the data. At present experts generally agree that phosphorus chemistry reflects the health status of the tissue. But can it identify the specific cause of dysfunction? The answer to that question awaits the continued development of a technology that first took root in physics laboratories 40 years ago.

—Greg Freiherr

Development of the loop-gap coil was supported primarily by the Biomedical Research Technology Program of the NIH Division of Research Resources through its National Biomedical Electron Spin Resonance Center at the Medical College of Wisconsin in Milwaukee. Additional support was received from the National Science Foundation through its Biophysics Program. Studies of the coil's effectiveness in imaging and spectroscopically analyzing tissue were funded by the National Cancer Institute and by a grant from General Electric Medical System.

Additional reading:

1. Kneeland, J. B., Carrera, G. F., Ryan, D. L., Jesmanowicz, A., Froncisz, W., and Hyde, J. S., Magnetic resonance imaging of a fractured temporomandibular disc prosthesis: A case report. *Journal of Computer Assisted Tomography* 11:199–200, 1987.
2. Middleton, W. D., Kneeland, J. B., Carrera, G. F., Cates, J. D., Kellman, G. M., Campagna, N. F., Jesmanowicz, A., Froncisz, W., and Hyde, J. S., High resolution magnetic resonance imaging of the normal rotator cuff. *American Journal of Roentgenology* 148:559–564, 1987.
3. Kneeland, J. B., Jesmanowicz, A., Froncisz, W., Grist, T. M., and Hyde, J. S., High-resolution MR imaging using loop-gap resonators: Work in progress. *Radiology* 158:247–250, 1986.
4. Hyde, J. S., Froncisz, W., Jesmanowicz, A., Grist, T. M., and Kneeland, J. B., Planar-pair local coils for high resolution magnetic resonance imaging, particularly of the temporomandibular joint. *Medical Physics* 13:1–7, 1986.
5. Froncisz, W., Jesmanowicz, A., Kneeland, J. B., and Hyde, J. S., Counter rotating current local coils for high resolution magnetic resonance imaging. *Magnetic Resonance in Medicine* 3:590–603, 1986.

For Additional Information:

To locate information or professional contacts on this effort, contact:

Research Resources Information Center, 1601 Research Blvd., Rockville, MD 20850 (301) 984-2870

Refer to item XI, No. 7/TN

NASA Tech Brief
National Aeronautics and Space Administration
Ames Research Center, Moffett Field, California

Licensing Opportunity

Portable Speech Synthesizer

A compact speech synthesizer can be a useful traveling companion to the speech-handicapped.

Mute and other people with speech impairments can communicate better thanks to a portable speech synthesizer. A user simply enters a statement on a keyboard, and the synthesizer converts the statement into spoken words. Battery-powered and housed in a briefcase, the synthesizer can be easily carried on trips and stows conveniently under an airplane seat. The unit can be used on telephones and in face-to-face communication.

The synthesizer consists of a microcomputer with a memory-expansion module, a speech-synthesizer circuit, batteries, a recharger, a dc-to-dc converter, and a telephone amplifier. These components, all of which are commercially available, fit neatly in the 17- by 13- by 5-in. (43- by 33- by 13-cm) briefcase. The unit weighs about 20 lb (9 kg) and can be operated and recharged from an ac receptacle.

A user turns on the power and selects an appropriate text-to-speech program from the microcomputer menu. If the conversation is to be by telephone, the user first plugs a modular telephone jack in the unit into the phone. The user enters a statement on the keyboard, and the computer stores it in memory. When the user touches the return key, the computer converts the stored statement into speech. Commonly used phrases — for example, those used to begin telephone calls — can be included in the program and can be

activated by pressing single keys.

This work was done by Gilbert H. Leibfritz and Howard K. Larson of **Ames Research Center**.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center Refer to ARC-11595./TN

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(415) 694-6370
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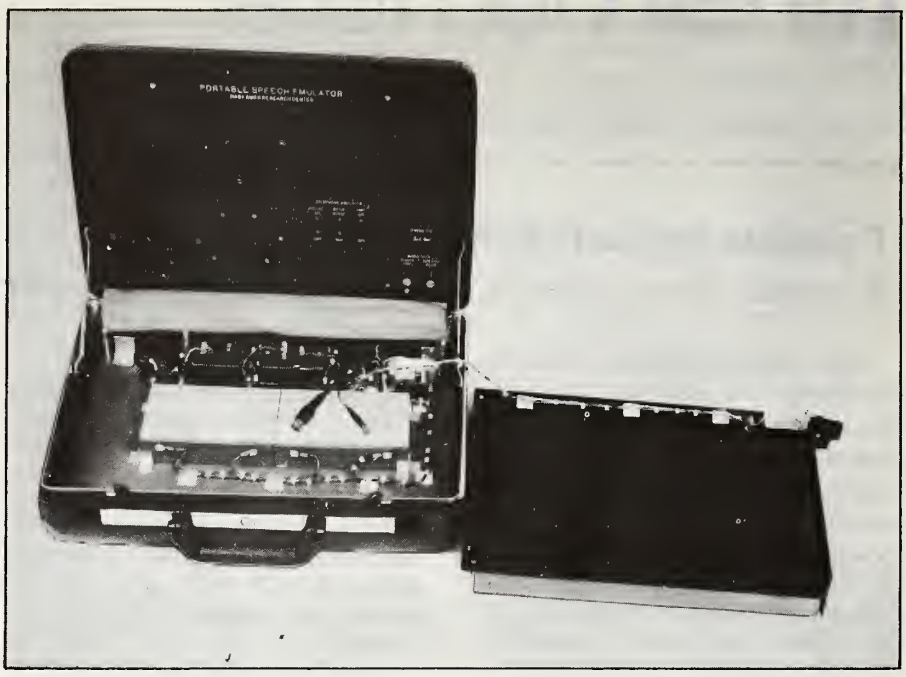


The **Circuit Boards** of the speech synthesizer and the telephone amplifier and its speakers and microphone are located behind the panel of the lid of the attache' case, as are all of the controls for those items and the telephone modular jacks. Located in the lower part of the case are the batteries, which are covered by a panel on top of which is the space for the microcomputer and the necessary cables. The microcomputer is removable so that it can be used for normal computations.

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD. 21240; (301) 621-0100 Ext. 241*

REFER TO THE NUMBER LISTED AT THE END OF THE ARTICLE

Natural Resources Technology & Engineering

58 Better Stoppings for Mines With Large Entries

59 Climatic Data for Chernobyl Nuclear Accident Studies

Technology News

From the Bureau of Mines, United States Department of the Interior

No. 275

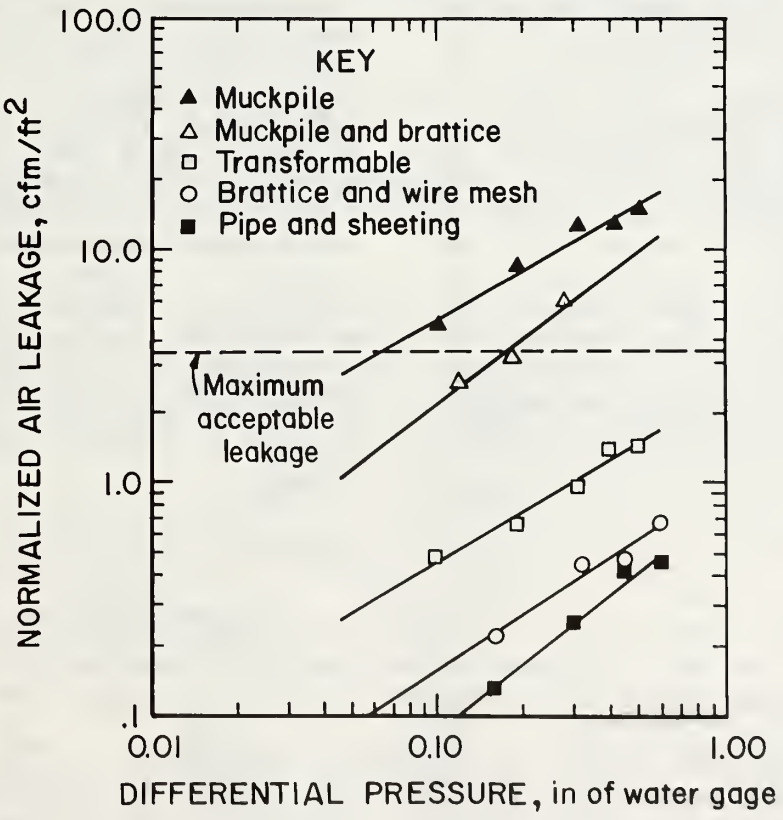
Better Stoppings for Mines With Large Entries

Objective

Provide improved permanent stoppings designed specifically for use in mines with large cross-sectional entries.

Approach

The large entry sizes in many mines, such as oil shale, salt, and limestone, make the conventional stopping construction techniques used in smaller opening mines unacceptable. The Bureau of Mines and Colorado Mining Association jointly sponsored a contract to design and test new or modified stopping concepts for these mines. The most promising concepts were then tested in an oil-shale mine having 30-foot-high by 55-foot-wide mine entry openings. All stopping designs tested were evaluated in terms of cost, air tightness, and resistance to blast damage.



Measured post-blast leakage as a function of differential air pressure.

Designs Tested

Five permanent stoppings concepts were tested:

- Pipe and Sheeting Stopping: This stopping is formed by telescoping 5-and 6-inch square section steel tubes, which are set in holes in the mine floor and attached to angle irons anchored in the roof with resin bolts. Panels of 16-gage corrugated galvanized steel sheets are then attached to the tubes using self-tapping screws. All joints and the entire perimeter are then sealed with rigid foam.
- Brattice and Wire Mesh Stopping: Damage-resistant brattice, which consists of standard brattice panels hung side-by-side and joined by Velcro seals, (see *Technology News* #59) is sandwiched between layers of 12-gage chain link fence to form this stopping. The wire fencing is attached to angle irons anchored to the roof and

floor with resin bolts. The edges of the fencing are wired together, and the brattice seams and the stopping perimeter are sealed with rigid foam.

- Transformable Stopping: To make this stopping, damage-resistant brattice is converted to a permanent stopping. After the brattice is hung, frames of 6-inch channel iron, 12-feet wide, are fabricated on the ground, and one side is covered with 12-gage chain link fencing. These panels are raised against the brattice and anchored to the roof and floor with resin bolts. The chain link fencing is secured at the ribs using ram set masonry nails. The entire stopping is then sprayed with rigid foam.
- Muckpile Stopping: This stopping is constructed by placing mined oil shale in the crosscut with a front end loader and shaping it to within 6 ft of the roof with a bulldozer. The final 6 ft are pneumatically stowed with oil shale of less than 3-inch size. Any small remaining gaps at the roof are closed with foam.
- Muckpile and Brattice Stopping: The stopping is formed by placing mined oil shale in the crosscut to within 12 feet of the roof, and closing off the remaining opening with a brattice curtain. The sides and roof are sealed with rigid foam. A 2-foot flap of excess brattice on top of the muckpile is sealed with oil shale.

Evaluation Results

Air leakage through the stoppings was measured as a function of the differential pressure. Measurements were made immediately after stopping construction and following a full-scale, 1,800-pound ANFO face blast about 700 feet from the muckpile and brattice stopping, and about 1,500 feet from the other stoppings (see the graph comparing the post-blast leakage with what the oil-shale industry considers acceptable leakage). Peak blast air pressures at the stoppings ranged from 2.3 to 4.2 inches water gage. The blast tore the curtain from the roof on the muckpile and brattice stopping, necessitating repairs before post-blast leakage could be measured. The other four stoppings were not damaged. With the exception of the muckpile stopping, pre- and post-blast leakage for the stoppings were about the same. The leakage across the muckpile stopping increased significantly, probably due to continued settling. The high leakage rates for muckpile-type stoppings are surprising, especially since they are now used in many mines with large openings. The following table presents pre- and post-blast leakage and total construction cost for each stopping type evaluated.

In general, the tests showed that:

- Large size stoppings can be built with low leakage at an acceptable cost.
- High initial construction costs of some stoppings can be amortized by savings through reduced air leakage and low maintenance costs.
- Blasting damage to permanent stoppings can be prevented by locating them at reasonable distances from the blasting face.

For More Information

A Bureau of Mines final contract report entitled, "Improved Stopping, Door and Overcast Construction for Oil Shale Mines, Contract no. J0145020, June 1986, is available. For a single copy of this report or for answers to technical questions please contact Mr. Edward D. Thimons, the technical project officer for this research, at the Bureau of Mines, Pittsburgh Research Center, P.O. Box 18070, Pittsburgh, PA 15236; telephone, (412) 675-6683.

Stopping Type	Construct Cost ($)	Leakage (cfm/1000ft² at 0.1 in w.g.) Pre-blast	Post-blast
Pipe and Sheeting	8,858	80	80
Brattice and Wire Mesh	3,018	260	160
Transformable	6,747	320	460
Muckpile	5,789	3,610	5,130
Muckpile and Brattice	2,412	2,080	2,170

NOAA Technology Brief

National Oceanic and Atmospheric Administration

National Environmental Satellite, Data, and Information Service
National Climatic Data Center

Climatic Data for Chernobyl Nuclear Accident Studies

The National Climatic Data Center (NCDC) has compiled a data base for the period April 25 through May 30, 1986 for the Chernobyl, U.S.S.R., incident. This data base describes the weather for the Northern Hemisphere during and following the incident. Researchers and engineers can use the data to determine such things as the direction of movement and dissipation of the radioactive cloud and the areas of likely fallout from the cloud.

This special data base is composed of three subsets. Subset 1 contains 6-hourly synoptic surface and upper-air observations available form the Global Telecommunications System (GTS) at the World Meteorological Center in Washington, D.C. The kinds of observations found in the 6-hourly synoptic surface data are: temperatures, wind velocity, and values of pressure. Upper air observations consist of temperature and wind data and computed values of pressure, density, and speed of sound. The GTS promotes rapid and reliable collection, exchange, and distribution of data gathered by a global observing system and processed information available through world and regional meteorological centers.

Subset 2 contains 6-hourly precipitation data extracted from GTS surface synoptic reports and an additional 3,000 United States hourly precipitation observations summarized in 6-hourly reports. Additional supplementary precipitation data will be added as received from Northern Hemisphere countries.

Subset 3 contains satellite sounding data. These data provide three - dimensional observations of the atmosphere from the surface to approximately 65.5 km. Atmospheric temperature and thickness values between 1,000 mb and 20 standard levels up to 1 mb in geopotential meters are derived from some 8,000 daily soundings for the Northern Hemisphere.

NCDC has placed the Chernobyl data base in the collocated World Data Center-A for Meteorology in Asheville, N.C. The cost of the data is that of preparing copies of magnetic computer tapes.

Similar data are available for other areas of the world and different time periods. Such data can be used by scientists and engineers to analyze the movements of other types of clouds and of atmospheric constituents.

For additional information on the Chernobyl data base or on similar data bases, contact NOAA ORTA, Suitland Professional Center (SPC), Room 307, Washington, D.C. 20233. Telephone (301) 763-4240.

Physical Sciences

60 Mathematical Models for Doppler Measurements — Error analysis increases the precision of navigation.

61 Electron-Spin Resonance in Boron Carbide — Samples exhibit Curie-law behavior in the temperature range of 2 to 100 K.

62 ESR Analysis of Polymer Photo-Oxidation — Electron-spin resonance identifies polymer-degradation reactions and their kinetics.

63 Glass-to-Metal Seal Against Liquid Helium — Superfluid helium II does not leak through this seal on a transparent container.

Software

64 DATAPLOT — An interactive high-level language for Graphics, Non-linear Fitting, Data Analysis, and Mathematics. Version 87.1

Testing & Instrumentation

65 Application of Collinear Laser Spectroscopy on Fast Atom Beams to Measure Nuclear Properties

66 System Developed to Digitally 'Map' Atomic Composition

67 Nuclear Orientation Equipment Available for Collaborative Work

68 Remote Optical Combustion Analyzer — Delicate instruments are kept far from the combustion process. (Licensing Opportunity)

69 Noncontacting Thermometer — An instrument would measure interior and surface temperatures. (Licensing Opportunity)

Other items of Interest

50 Polyimides Containing Carbonyl and Ether Connecting Groups — Semicrystallinity gives rise to tough, solvent-resistant polymers. (Licensing Opportunity)

NASA Tech Brief
National Aeronautics and Space Administration

Mathematical Models for Doppler Measurements

Error analysis increases the precision of navigation.

A report presents improved mathematical models for the analysis of Doppler measurements and measurement errors in spacecraft navigation. To take advantage of the potential navigational accuracy of Doppler measurements, precise equations relate the measured cycle count to the position and velocity. Drifts and random variations in transmitter and receiver oscillator frequencies are taken into account. The mathematical models can also be adapted to aircraft navigation, radar, sonar, lidar, and interferometry.

Because the frequency errors of the transmitter and receiver oscillators contribute to the Doppler errors, the report begins with a discussion of the frequency-error statistics. The difference between the actual and nominal frequencies of an oscillator is represented as the sum of a bias error (which varies approximately linearly with time), a time-correlated random error, and a non-time-correlated random error consisting of small, rapid fluctuations.

The one-way Doppler model is developed for transmission to a moving receiver. The receiver converts the incoming signal to a new frequency, called the composite frequency, which equals a constant bias frequency plus some chosen multiple of the Doppler frequency shift measured by the receiver. The number of cycles of the composite frequency during a given interval is expressed theoretically in terms of the receiver position and velocity and the various oscillator frequencies: it is equivalent to a range measurement plus a constant of integration. The rate of change of the constant of integration is treated as an exponentially correlated random variable, the parameters of which are used to design a Kalman filter.

In a high-precision Doppler system, the composite frequency is integrated in time by counting positive-slope zero crossings of the signal to obtain the cycle count. Equations are derived for the effect, upon the composite frequency and cycle count, of errors in the transmitter and receiver oscillator frequencies: thus, one can predict the cycle count of real, imperfect equipment.

Similar considerations also lead to two- and three-way Doppler models and the associated errors. In this case, the constant of integration is treated as a random-walk variable. With the drifts removed by Kalman filtering, the measurement noise becomes uncorrelated in time, and the navigational filters become optimal.

This work was done by William M. Lear of TRW, Inc., for **Johnson Space Center**
To obtain a copy of the report, "Mathematical Models for Doppler Measurements," MSC-21150 /TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD. 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and Space Administration

Electron-Spin Resonance in Boron Carbide

Samples exhibit Curie-law behavior in the temperature range of 2 to 100 K.

A technical paper presents studies of electron-spin resonance (ESR) of samples of hot-pressed B_9C, $B_{15}C_2$, $B_{13}C_2$, and B_4C. Boron carbide ceramics are refractory solids with high melting temperatures, low thermal conductivities, and extreme hardnesses. They show promise as semiconductors at high temperatures and have unusually large figures of merit for use in thermoelectric generators.

At 2 K, the ESR spectra for all four compositions can be explained by a single Lorentzian absorption with a relatively narrow line width and free-electron gyromagnetic ratio. The ESR line width of B_4C remains narrow between 2 and 295 K, whereas those of the other three samples (which contain smaller proportions of carbon) increase by a factor of 20 over the same temperature range. Above the temperature of 20 K, the line shape of the ESR signal in the latter three samples can be expressed as a sum of two Lorentzians with different line widths.

The integrated intensities of the ESR signals in all four samples follow a Curie law below 100 K, with a Curie constant corresponding to spin concentrations of 1.8 to 3.6×10^{19} per gram. No prior experiments with boron carbides showed this simple behavior over a temperature range where the temperature increased by a factor greater than 50 (i.e., over the range 2 to at least 100 K), a result tentatively attributed to the high quality of the samples used. Although these values are in agreement with data on the static magnetic susceptibilities of samples cut from the same hot-pressed billets, they are about two orders of magnitude less than the carrier densities estimated from transport measurements. This suggests that the carriers are spinless bipolarons.

At room temperature the ESR spectra include both absorption and dispersion terms, indicating significant electrical conductivity at microwave frequencies. The estimated microwave resistivity, 0.3 Ω·cm, agrees well with the dc value of 0.5 Ω·cm.

This work was done by Charles Wood, Eugene L. Venturini, Larry J. Azevedo, and David Emin of Caltech for **NASA's Jet Propulsion Laboratory**. *"Electron Spin Resonance Study of Hot-Pressed Boron Carbide," NPO-16884 /TN*

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

ESR Analysis of Polymer Photo-Oxidation

Electron-spin resonance identifies polymer-degradation reactions and their kinetics.

The processes of photo-oxidation and aging in polymeric materials have been observed at the molecular level by using the electron-spin-resonance (ESR) technique combined with in situ ultraviolet irradiation of the polymers in atmospheres with different oxygen concentrations. Unlike the traditional approach to the study of such aging processes, which has been to monitor such macroscopic mechanical properties as stress and strain, the new technique enables the derivation of a kinetic model of the specific chemical reactions involved in the degradation of a particular polymer. The detailed information provided by the new method should enable the prediction of aging characteristics long before the manifestation of macroscopic mechanical properties.

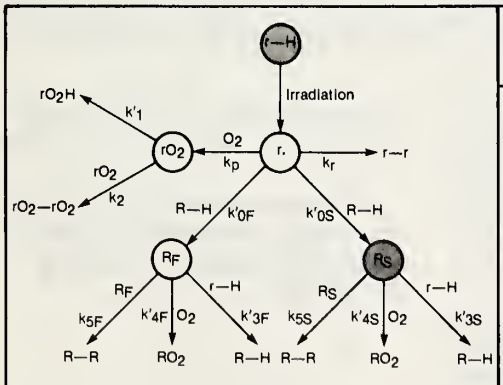
In the experiments, 25-mg samples of poly(n-butyl acrylate) were deposited as thin layers on the insides of glass tubes. The tubes were sealed after introducing oxygen at partial pressures from 1 to 760 torr (130 to 100,000 Pa). Each sample was placed inside an ESR microwave cavity with a grid opening for ultraviolet irradiation from an enhanced xenon lamp, the spectrum of which extended down to a wavelength of 250 nm.

Photo-oxidation was stimulated by turning the ultraviolet light on and off at preset intervals. During each irradiation period, there was a subperiod during which the population of radicals produced by photo-oxidation rose, followed by a subperiod of constant illumination during which the radical populations remained constant, followed by a subperiod of no illumination during which the radical populations decayed. For kinetic studies of a particular reaction product, the magnetic field of the ESR spectrometer was set at the corresponding peak of the radical spectrum.

The kinetic model and its rate constants derived from the ESR measurements on poly(n-butyl acrylate) are shown in the figure. While the peroxy and tertiary radicals are the major radical intermediates as required by the previously accepted mechanism, the model deduced from these measurements shows significant differences in the kinetics of the major intermediates and in the mechanism of their formation. The macromolecular peroxy radical is formed both directly from the intermediate short-lived radicals and in a parallel reaction of O_2 with the tertiary radicals.

There are at least two different types of tertiary radicals, one smaller and more mobile than the other. Under the illumination conditions used, cross-linking by recombination of peroxy radicals is the major degradation pathway; the cross-linking of tertiary radicals is important only in oxygen-starved samples.

This work was done by Soon Sam Kim, Ranty Hing Liang, Fun-Dow Tsay, and Amitava Gupta of Caltech for **NASA's Jet Propulsion Laboratory**. *NPO-16847 /TN*



Note: r-H denotes the polymer before irradiation.

Radicals	Steady-State Populations	Rate Processes	Rate Constants at 25°C
r. (Intermediate)	$[r\cdot]_{eq} = 2.4 \times 10^{-6}$ m/L	Reaction with O_2	$k'_p = 700$ L m^{-1}s^{-1}
		Recombination	$k_r = 8 \times 10^5$ L m^{-1}s^{-1}
R_F and R_S (Tertiary)	$[R_F]_{eq} = 4.4 \times 10^{-6}$ m/L	Formation of R_F	$k_{0F} = 5 \times 10^{-1}$s^{-1}
	$[R_S]_{eq} = 2.9 \times 10^{-6}$ m/L	Formation of R_S	$k_{0S} = 1 \times 10^{-1}$s^{-1}
		Abstraction by R_F	$k'_{3F} = 1.3 \times 10^{-1}$s^{-1}
		Abstraction by R_S	$k'_{3S} = 8 \times 10^{-3}$s^{-1}
		Reaction of R_F with O_2	$k'_{4F} = 700$ L m^{-1}s^{-1}
		Reaction of R_S with O_2	$k'_{4S} = 300$ L m^{-1}s^{-1}
		Recombination of R_F with self	$k_{5F} = 5 \times 10^4$ L m^{-1}s^{-1}
		Recombination of R_S with self	$k_{5S} = 3 \times 10^3$ L m^{-1}s^{-1}
rO_2 and RO_2 (Peroxy)	$[rO_2\cdot + RO_2\cdot]_{eq} =$ 8.0 $\times 10^{-6}$ m/L	Abstraction	$k_1 = 2 \times 10^{-2}$s^{-1}
		Recombination with self	$k_2 = 5 \times 10^4$ L m^{-1}s^{-1}

The **Photo-oxidation of Poly(n-Butyl Acrylate)** produces intermediate radical species. This reaction sequence and the associated rate constants were deduced from ESR measurements of the polymer during and after illumination with ultraviolet light.

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Glass-to-Metal Seal Against Liquid Helium

Superfluid helium II does not leak through this seal on a transparent container.

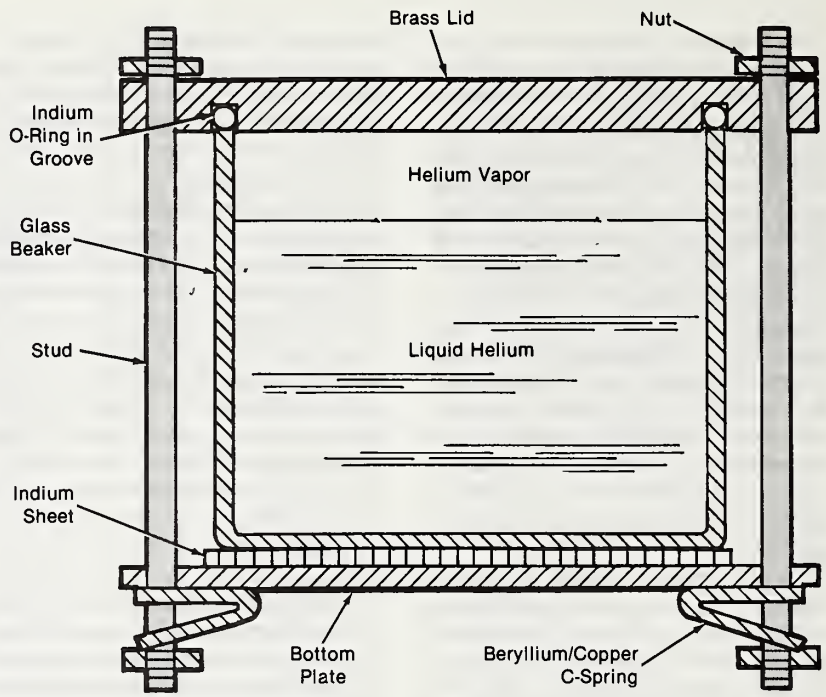
A simple compression joint with an indium gasket forms a demountable seal for superfluids. The seal was developed for a metal lid on a glass jar used in experiments on liquid helium. The glass container allows the contents to be viewed for such purposes as calibration of liquid-level detectors and adjustments of displacement plungers. Until now, demountable, leak-tight glass-to-metal joints have not been able to withstand the repeated thermal cycling of cryogenic procedures.

The seal contains liquid helium even when its temperature drops below 2.19 K — the λ point at which the helium becomes helium II, a zero-viscosity fluid that can flow through pores as small as 10^{-6} cm. The seal is made from inexpensive, commercially available materials and parts; special metals, special glasses, and skilled glassblowing are unnecessary.

The jar is made from an ordinary Pyrex (or equivalent) glass beaker. The flared top is removed with a glass saw. To remove gross irregularities from the newly exposed edge, the edge is ground on a flat table with 600-grit abrasive paper soaked with alcohol. Grinding continues until the exposed edge appears uniformly gray. The edge is then fire-polished.

The lid is machined from brass 0.125 in. (3.2 mm) thick. A groove is machined in the lid to accommodate an O-ring of indium wire 0.050 in. (1.27 mm) in diameter. Electrical and mechanical connections to the jar pass through the lid.

The jar is pressed tightly against the O-ring by a spring-loaded bottom plate (see figure). Eight studs equally spaced around the lid perimeter hold the plate against the beaker. The beryllium/copper C-shaped springs have enough extra travel to compensate for the cold flow of the indium gasket over time. The O-ring seal should be tightened in stages.



Made From Stock Materials, a glass experiment cell holds superfluidic helium, even though no special provisions are made to prevent thermal shock in cryogenic experiments. The brass lid and indium O-ring can readily be used on a metal jar when the cell contents do not have to be visible.

The indium O-ring must be replaced every time the seal is broken. A sheet of indium 0.030 in. (0.76 mm) thick under the jar helps to distribute the compressive load over the irregular glass bottom. Unlike the O-ring, the sheet can be used during many experiments.

In each of a series of 15 experiments, the sealed, helium-filled jar was lowered into a conventional double Dewar flask having window strips in both the inner and outer containers. The outer container was filled with liquid nitrogen at 77 K. After 4 to 6 hours, liquid helium at 4 K was poured into the inner container, and the measurements were taken. There was no noticeable leakage of helium into or out of the jar.

This work was done by John L. Watkins and John R. Gatewood of Caltech for **NASA's Jet Propulsion Laboratory**.
NPO-16308 /TN

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NBS technology update

National Bureau of Standards
U.S. Department of Commerce
Gaithersburg, MD 20899

DATAPLOT: An Interactive High-Level Language for Graphics, Non-Linear Fitting, Data Analysis, and Mathematics. Version 87.1

DATAPLOT is a portable, high-level interactive language/system for graphics, fitting, data analysis, and mathematics. It has wide applicability, especially in a research/ scientific/ engineering environment. Recent enhancements allow DATAPLOT to be run as a menu system. Such menus are completely user-definable thereby allowing them to be fully tailored to one's local needs and environment.

For Additional Information:

For information about ordering this software, contact the

NTIS Computer Products Center, NTIS, 5285 Port Royal Road, Springfield, VA 22161; (703) 487-4763.

Refer to PB87-160990/NAC

Price: $1,900

The program is written in FORTRAN for implementation on a number of host computers, such as, UNIVAC, IBM, CYBER, DEC VAX, and others. Approximately 600K bytes of main memory are required.

Technology Application

Oak Ridge Associated Universities

Application of Collinear Laser Spectroscopy on Fast Atom Beams to Measure Nuclear Properties

A sensitive laser spectroscopy system based on a collinear beams technique has been developed at the University Isotope Separator at Oak Ridge, a basic nuclear physics research facility operated by Oak Ridge Associated Universities. The ion beam from the separator is electrostatically deflected to be collinear with a laser beam. The ions are then neutralize, in passing through a charge exchange cell containing an alkali metal vapor. Laser light is used to excite atomic transitions in the neutral atoms. The effects of laser excitation are detected and recorded as a function of laser frequency. Such measurements enable researcher: to precisely define the hyperfine structure of atomic levels that result from the interaction of the nucleus with the atomic electrons.

Use of the laser optical spectroscopy system allows a more precise measurement of hyperfine structure and thus provides an independent means of determining certain groundstate properties of nuclei, in particular the ground-state spins of odd-mass nuclei.

For Additional Information:

Dr. Kennon Carter
Oak Ridge Associated Universities
P.O. Box 117
Oak Ridge, TN 37831-0117
(615) 576-2642

Refer to DOE/ORAU/010/TN

NBS technology update

National Bureau of Standards
U.S. Department of Commerce
Gaithersburg, MD 20899

System Developed to Digitally "Map" Atomic Composition

NBS has teamed with the National Institutes of Health to develop a system that uses digital computer technology coupled with electron beam instruments to "map" the distribution of chemical elements on the surfaces of a variety of samples. The system has many applications, including characterization of microstructures in various materials and the linking of disease to chemical imbalances in the body. The key technical advantage to the system is that it can create compositional images which display both the type and number of atoms at sample sites 1 micrometer or finer in dimension. That is, besides giving qualitative information on which elements are distributed in the sample, the system also provides a complete quantitative analysis at every one-micrometer-wide point. Researchers can view these dual functions through a color-enhanced video image of the sample. Other devices on the market are limited in their ability to provide a complete quantitative analysis.

MEDIA CONTACT: John Henkel, 301/975-2762

For Additional Information:

To discuss this effort further, contact Dr. Dale Newbury, Chemistry Bldg., Room A121, National Bureau of Standards, Gaithersburg, Md. 20899; (301) 975-3921

Technology Application

Oak Ridge Associated Universities

Nuclear Orientation Equipment Available for Collaborative Work

Nuclear orientation equipment that will enable new types of experiments in nuclear structure and in solid state physics to be conducted has recently been installed at the University Isotope Separator at Oak Ridge, a basic nuclear physics facility operated by Oak Ridge Associated Universities. The orientation equipment will use a magnetic field and an extremely low temperature produced by a helium dilution refrigerator to align nuclei, thus permitting measurements of specific nuclear properties, such as ground-state spins and moments as well as excited-state spins and transition mixing ratios. It also has the potential for use in the determining site locations in crystals for doping of semiconductors.

For Additional Information:

Dr. Kennon Carter
Oak Ridge Associated Universities
P.O. Box 117
Oak Ridge, TN 37831-0117
(615) 576-2642

Refer to DOE/ORAU/011/TN

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Remote Optical Combustion Analyzer

Delicate instruments are kept far from the combustion process.

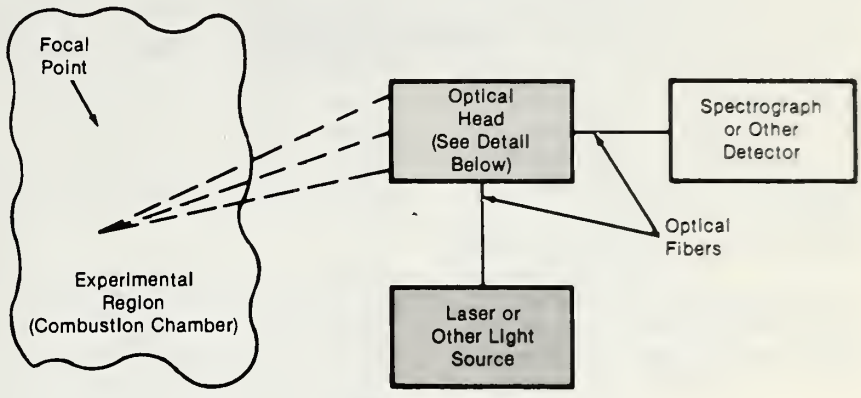
A rugged optical head enables remote, nonintrusive measurements of temperatures and chemical compositions in hostile environments — in combustion chambers, for example. The head brings laser light to the system under test and carries system-scattered light to a spectrograph or other instrument.

The head is mounted securely on an optical port in the test system. Optical fibers transmit light from the laser to the head and from the head to the spectrograph. Light from the laser diverges from the fiber tip and is collimated by lens 1 (see figure). The nearly parallel light rays from lens 1 are turned by a prism so that the light bundle coincides with the optical axis of the head. The laser radiation is then brought to an intermediate focus by lens 2 and finally is refocused on the measurement volume by lens 3. Lenses 2 and 3 can be translated with respect to each other so that the measurement region surrounding the final focal point can be moved along the optical axis of the head to the desired location within the system chamber. The axis of the measurement volume can be slued by prisms or mirrors.

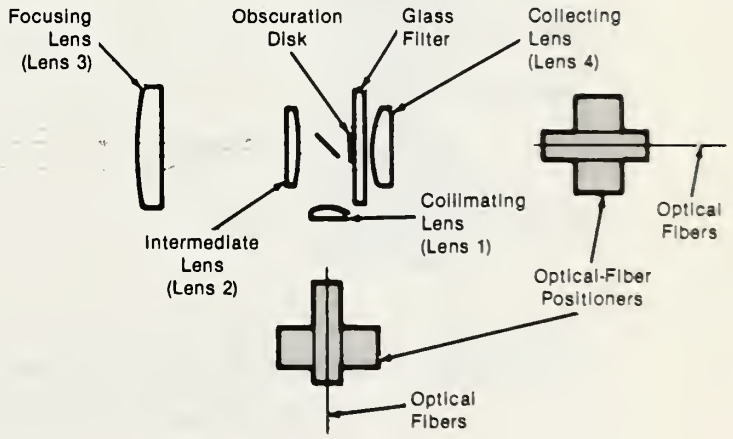
Radiation backscattered from the measurement volume is collected and collimated by lenses 3 and 2. Most of the backscattered light passes around the prism and through the filter, which blocks the unwanted wavelengths. The light then enters lens 4, which focuses it into the optical fiber leading to the spectrograph. An obscuration disk can be used to restrict the depth of field of the optics.

The light delivered to the spectrographic equipment is analyzed to determine its spectral distribution or intensity. From these data, the temperature and chemical composition of the material in the measurement volume can be determined.

Currently-available glass optical fibers are well suited to the transmission of near-infrared light. When data are needed at green and blue wavelengths, fibers are less efficient carriers but nevertheless are usable if the fiber lengths are less than about 100 meters. Fluorescence measurements require higher photon energies, and the probing radiation therefore must be in the ultraviolet region. Even though fiber-transmission characteristics are not favorable at these short wavelengths, the measurement scheme may still be useful if a source of sufficiently high power is available to overcome the attenuation in the fibers, if the fibers are not degraded by



OPTICAL SYSTEM



DETAIL OF OPTICAL HEAD

The **Optical Head Beams Light** from a laser source to a test chamber, then collects the backscattered light from the chamber and sends it to spectrographic equipment. The lenses, prisms, and optical-fiber tips can be moved so that the focal point can be precisely positioned in the test chamber.

the high power dissipation in them, and if a relatively low photon flux is acceptable in the measurement volume.

This work was done by A. C. Eckbreth and J. A. Shirley of United Technologies Research Center for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center
Refer to MFS-28146./TN

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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Noncontacting Thermometer

An instrument would measure interior and surface temperatures.

A proposed laser/ultrasonic thermometer would measure the bulk and surface temperatures of a part without physical contact — unlike a pyrometer, which measures only the temperature of the surface. No sensors or wire connections would be needed on the part, which may be moving or stationary. Problems of bonding sensors, of mutual diffusion of materials between the sensor and the part, and of disturbances of fluid and heat flows by the sensor would thus be avoided. A single thermometer could be used to measure many parts remotely; for example, the blades of a rotating turbine.

According to the concept, a light pulse from a laser would be directed at the part, generating in it an ultrasonic pulse composed of both surface and bulk acoustic waves. The phase variations induced in a separate laser beam by reflection from the waves on the surface would be used to measure the start of a pulse and the echoes returning both along the surface and to the surface through the bulk of the part.

Since the time of passage of an acoustic pulse through the bulk is a function of the bulk temperature, the average bulk temperature could be determined directly from the echo delay. In addition, if the surface acoustic wave across the part were to be measured, the surface temperature could be determined. The duration, repetition rate, and other parameters of the pulses and the position of the excitation beam on the part could be selected so that both the surface and the bulk temperatures could be measured by the same instrument.

This work was done by Lynn M. Wyett of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center Refer to MFS-29277 /TN

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A06 through A09	19.95
A10 through A13	25.95
A14 through A17	32.95
A18 through A21	38.95
A22 through A25	44.95
A99	Call for price

Customers in Canada, United States, and Mexico use this schedule. Other addresses should write for the price listing, number PR-360-4.

Prices effective January 1, 1988

Use this form ONLY to order reports designated as available from NTIS

MAIL ORDER TO: National Technical Information Service
U.S. DEPARTMENT OF COMMERCE
5265 Port Royal Road
Springfield, VA 22161

Send me the reports I have selected on this form. I have placed order numbers in appropriate blanks and have indicated the quantity. IF ADDRESS LABEL

Last Name: .....

Title: .....

Company/Organization: .....

Address: .....

City/State/Zip: .....

Telephone Number: .....

METHOD OF PAYMENT

☐ Check enclosed payable to NTIS for $ .....

☐ Charge to my NTIS Deposit Account, No: .....

☐ Purchase order number: .....

Charge to: ☐ American Express ☐ VISA ☐ MasterCard

Card Number: .....

Expation date: .....

Signature: .....
(Required to validate order)

NTIS ORDER NUMBER (Use only for backup reports stated as available from NTIS)

NTIS Order Number	*Price**	*Quantity*	*Total Price*
	Shipping and handling fee		$3.00
	Total		

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- Physical Sciences
- Transportation

Route To: